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ELEMENTARY LESSONS IN PHYSICS

BY
J. B. GIFFORD



TEACHER'S EDITION



THOMPSON,
BROWN & CO.

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ELEMENTARY LESSONS IN PHYSICS.

BY

JOHN B. GIFFORD,

SUPERINTENDENT OF SCHOOLS, PEABODY, MASS.

TEACHER'S EDITION.

THOMPSON, BROWN, AND COMPANY,

BOSTON.

CHICAGO.

Educ 218.94.418

Harvard College Library.

Dec. 20, 1918.

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JOHN WILSON AND SON, CAMBRIDGE, U. S. A.

PREFACE.

THE following Lessons have been growing into their present form for several years, during which time they have been used in classes under the supervision of the author. Within the past year they have been revised, with the aim of adapting them to general use.

It is confidently hoped that these Lessons will meet a want which is being increasingly felt by teachers and school officers for a suitable text-book to aid them in training the pupils of the upper grammar and lower high school grades to observe, to think, and to express thought, and in revealing to them some of the laws in accordance with which physical changes occur.

It has been the author's aim to guide the investigations of the learner by directions and questions so definite that he will generally be able to get the points desired without aid. Occasionally a question is asked which only a small proportion of the class may be able to answer; but the question should at least *secure the attention of all*, and prepare them to grasp the truth when it comes; and the closer workers will get the exercise which they need.

The *illustrations* have been introduced to show the *conditions* of the experiments, and not the *results*.

The Teacher's Edition contains some further hints on preparing apparatus, and statements of all observations, inferences, other facts and explanations called for in the Lessons.

Messrs. Frank L. Keith, J. M. Dill, and Charles F. King, of Boston, Mr. Clarence Boylston, of Milton, Mass., and Mr. Preston Smith, instructor in Physics, Brockton, Mass., have kindly read through these Lessons in manuscript or in proof, and suggested many valuable improvements.

Whatever of merit there may be in the aim and general plan of the work should be largely credited to my esteemed teacher in Physics, Mr. George H. Martin, of Boston.

JOHN B. GIFFORD.

JUNE, 1894.

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Those marked (*) are suggested for the later study, where the work is distributed through two or more years.

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SUGGESTIONS TO TEACHERS.

PUPILS *may* perform *at home* such of the experiments as do not call for special apparatus. Each teacher must decide for himself whether this plan is the most satisfactory for his class.

Wherever the experiments are performed, each pupil should *observe and infer for himself*, and *commit to writing* the results of his work before they are reported in the class exercises.

These records may be made upon separate sheets of paper of uniform size, each statement marked to correspond with the directions in the manual. If only one observation is called for under an experiment, it is marked *Obs.* ; if more than one, they are numbered *Obs. 1, Obs. 2*, etc. In the same way inferences are marked, — *Inf.*, or *Inf. 1, Inf. 2*, etc. Other facts to be recorded under each experiment are usually numbered.

After these results have been reported and compared in the recitation, and opportunity given for correcting errors, by repeating experiments, it would seem well that they should be neatly recorded in note-books.

This material should form the *basis of much written language* work, in which the pupil should develop the subject assigned by *complete descriptions of experiments, with drawings of the apparatus* used.

For the *derivation of terms*, suggested as profitable language study, a list of the required prefixes and suffixes, with their meanings, will be found on page 157.

The work laid out in these Lessons may all be done with a class in a single year; but some will prefer to distribute it over a longer period, and the derivation of terms and many of the general topics *may be omitted* without hindering the study of the others.

ELEMENTARY LESSONS IN PHYSICS.

I. NATURE OF MATTER.

MATTER, IMPENETRABILITY.

OBSERVATION, DERIVATION, INFERENCE.

EXPERIMENT 1. (To be performed at home.)

FILL a bottle with water, and insert your pencil.

Observation. State what the water does.

(In NOTE-BOOK.*) *Experiment 1. Obs. Some of the water overflows.*

Inference. What causes it to do this?

(NOTE-BOOK.) *Inf. 1. The bottle was full of water, and there was no room for the pencil. So when the pencil was inserted some of the water must come out.*

1. How did you learn what the water did?

(NOTE-BOOK.) 1. *I saw it run over.*

Call a fact learned through the senses an *observation*.

* See preface for suggestions in regard to records in Note-book.

In the dictionary you will find *observe* given as formed from the Latin *observare*, meaning *to pay attention to, to watch*. After this is placed the suffix *tion*, meaning *the act of*.

Inf. 2. What is the meaning of the whole word as you get it from its formation?

(NOTE-BOOK.) Inf. 2. *From the meaning of the parts, it would mean the act of paying attention to, or watching.*

2. Can you see any connection between this meaning and the sense in which we have used it above?

(NOTE-BOOK.) 2. *The fact learned is the result of paying attention.*

This tracing out the origin of words is called *derivation*.

In this work always try to discover the connection between the original meaning of the word and the sense in which you find it used.

3. How did you learn *what caused* the water to run over in the above experiment?

(NOTE-BOOK.) 3. *I learned it by thinking.*

Call a fact obtained by thinking, or reasoning from other facts, an *inference*.

Give the derivation of this word.

(NOTE-BOOK.) Inference is formed from the Latin inferre, meaning *to bring forward*, and the suffix ence, meaning *the quality of, the act of, and sometimes the result of, or that which*. Here the sense seems to be *that which is brought forward by thinking*.

EXPERIMENT 2. (At home.)

Holding an inverted tumbler evenly above a basin of water, push it downward into the water.



Fig. 1.

Obs. Observe the height of the water under the tumbler.

Inf. 1. What keeps it from rising higher?

Inf. 2. Why does that prevent it from rising?

1. Name three other things that take up room.
2. Does a thought take up room?
3. Can you think of other things which do not?
Call that which occupies room *matter*.

BODY.

4. Name six different *pieces* of matter.
Call them *bodies*.
5. What, then, is a body?

SUBSTANCE.

6. Name six different *kinds* of matter.

Call each kind of matter a *substance*.

7. What is a substance ?

Derive *substance*.

Inf. 3. How many bodies can occupy the same space at the same time ?

Call the property of matter by which no two bodies can occupy the same space at the same time *impenetrability*.

Define *impenetrability*.

Derive the term.

Describe experiments showing the impenetrability of matter.

II. DIVISIONS OF MATTER.

MOLECULE, MASS.

EXPERIMENT 3. (At home.)

Break a lump of salt into several pieces.

Dry one small piece thoroughly, and powder as fine as possible in a mortar.

Notice the size of these particles.

Imagine the division to be continued until the smallest particles which can exist by themselves have been formed.

Call these *molecules*.

Thus, the smallest particles of any substance which can exist by themselves are called *molecules*.

Derive *molecule*.

Call any quantity of matter greater than a molecule a *mass*.

Derive *mass*.

1. Name six masses of matter.

COMPOUND.

Each of these molecules of salt is composed of the metal *sodium* and a green gas called *chlorine*.

Let the teacher show a piece of sodium, and prepare a little chlorine by adding sulphuric acid to a little bleaching powder in a test tube or large-mouthed bottle.

Be careful not to inhale much of the chlorine. Sodium should be handled with forceps or dry paper, and kept under petroleum or kerosene.

Obs. Describe sodium and chlorine.

Sodium and chlorine are always combined in *exactly the same proportion* to form salt.

Call a substance which, like salt, has been found to be composed of two or more different kinds of matter combined in definite proportions a *compound*.

Water, alcohol, acids, kerosene, and iron-rust are compounds.

2. Compounds are what kind of substances ?

Derive the term.

ELEMENT.

Sodium has never been separated into different kinds of matter. Neither has chlorine.

Call such substances *elements*.

3. What do you understand by "such substances" ?

Oxygen, hydrogen, nitrogen, carbon, iron, lead, tin, gold, and silver are some of the common elements.

Derive *element*.

ATOMS.

4. A molecule of salt contains what elements ?

Inf. How must the quantity of sodium in a molecule compare with the quantity of salt in the molecule ?

Call the smallest particle of matter which can exist combined with other particles an *atom*.

5. What is an atom ?

Derive the term.

6. Name the divisions of matter which we have considered.

7. Which of these have you seen?

Inf. 2. Do the others really exist?

SIZE OF MOLECULES.

EXPERIMENT 4. (At home.)

Add a drop of "bluing" to a tumbler of water.

Obs. State the effect.

Inf. 1. What gives the color to the "bluing"?

Inf. 2. What to the water in the tumbler?

Inf. 3. Where are these particles?

Inf. 4. What do you infer in regard to the size of the molecules of coloring matter?

The *odor* of a substance is supposed to be due to small particles of the substance floating in the air and coming in contact with the nerve of smell. A little sachet powder will fill the air with perfume for a long time without undergoing any sensible loss of weight.

Inf. 5. What do you infer from this in regard to the size of the molecules?

III. STATES OF MATTER.

1. LIQUIDS.

EXPERIMENT 5. (At home.)

Put your finger into water, and stir it round.

Obs. 1. Observe the ease with which the finger is moved through the water.

Inf. 1. Make an inference in regard to the movement of the particles of water among themselves.

Remove your finger, keeping the end downward.

Obs. 2. Observe what forms at the end.

Inf. 2. Infer whether the particles tend to separate or to cling together.

1. What two things do you find to be true of the particles of water?
2. Name three other substances of which the same is true.
3. What common name may you give to these substances?
4. What would you say that liquids are? (See question 1, above.)

Derive *liquid*.

2. SOLIDS.

5. Compare wood, iron, and glass with liquids.

In which of the above points do they agree?
(See question 1.)

In which do they differ?

EXPERIMENT 6. (At school.)

Fasten one end of a stick of sealing wax firmly in a horizontal position. Leaving the other end unsupported, suspend from it a weight of one quarter of a pound.

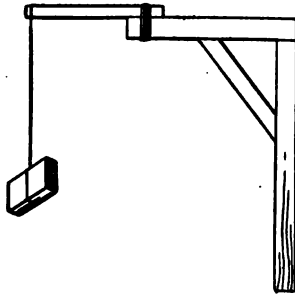


Fig. 2.

Obs. Let it remain for two days, observing the effect from time to time.

What is the result?

Inf. 1. Make an inference in regard to the movement of the molecules among themselves.

Inf. 2. Give a common name for such substances as wood, iron, and wax.

What have you found to be the distinguishing properties of these substances? (See question 5, above, and *Inf.* 1.)

How would you define solids.

Derive the term.

3. AERIFORM MATTER.

EXPERIMENT 7. (At school.)

Fit two horse-radish bottles with air-tight cork stoppers.

Half fill one bottle with water.

Cut off two pieces of glass tubing an inch longer than the height of the bottles, and one piece about two inches long.

To cut glass tubing make a notch on one side by two or three forward strokes of a triangular file, grasp the tube in both hands with the thumbs against it opposite, on the other side from the notch, and break by pressing out with the thumbs and drawing towards you with the outsides of the hands. Heat the ends of the pieces of tubing in the gas or alcohol flame until the sharp edges are rounded.

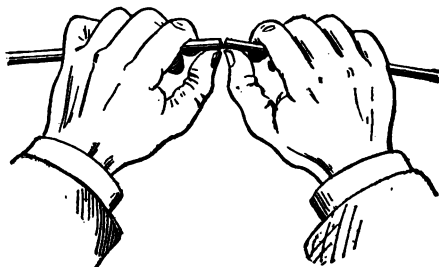


Fig. 3.

With a rat-tail file bore a hole in the stopper of the bottle containing the water, just large enough for the tube to fit air-tight; and push one of the longer tubes through the hole so that it will reach nearly to the bottom of the bottle.

In the same way fit the other two tubes into the stopper of the other bottle, letting them project about a quarter of an inch below the stopper.

Connect the two bottles by a piece of rubber tubing drawn over the ends of the glass tubes which project but little above the stoppers.

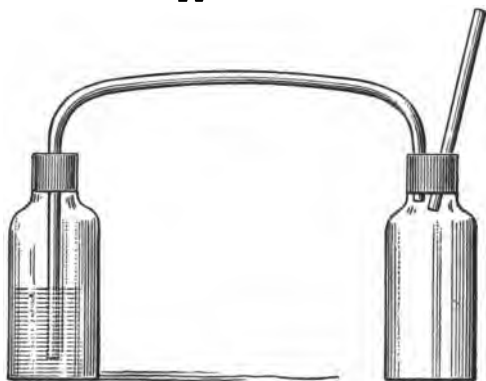


Fig. 4.

Obs. 1. What is in the bottles now ?

Taking the end of the projecting tube in the mouth, “draw out” as much air as you can.

Obs. 2. What is the effect ?

Inf. 1. Infer the cause of this.

Inf. 2. What tendency of the molecules of air is shown in this experiment ?

1. How does air differ from liquids ?

2. In what respect is it like liquids ?

Call such matter as air *aeriform matter*.

3. What are its distinguishing properties ? (See questions 1 and 2.)

4. Define aeriform matter.

Derive *aeriform*.

5. What other aeriform matter have you seen ?

6. What name is applied to both liquids, and aeriform matter ?

GAS AND VAPOR.

EXPERIMENT 8. (At school.)

Boil a little water in a test tube.

Obs. Notice what is formed, and where it goes.

Inf. 1. What is it formed from ?

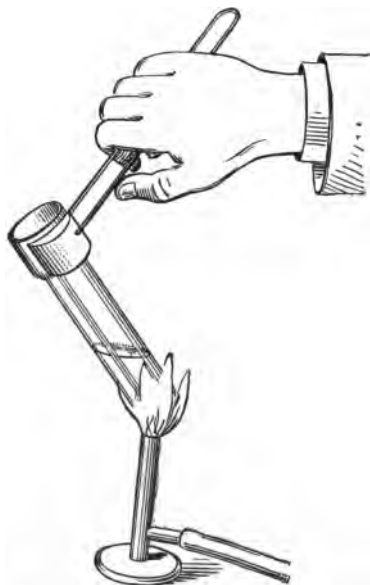


Fig. 5.

Inf. 2. When wet clothing dries where does the water go?

1. Can you see this water in the air?
2. In what state of matter is water ordinarily?
3. In what state of matter is this invisible water in the air?

Call such aeriform matter *vapor*.

4. How does it differ from air? (See question 2.)

Call such aeriform matter as air *gas*.

5. What other gases have you known?

Write a connected description of the different states of matter, showing by illustrations what each is.

IV. CHANGES IN MATTER.

1. CHEMICAL CHANGE.

EXPERIMENT 9. (At school.)

Place a little copper in a test tube.

Add about twice its weight of nitric acid.

Obs. Observe, and state the effect in the liquid, and above the liquid.

Inf. 1. Infer what gives the color to the liquid.

Would copper give it that color? Would nitric acid?

Inf. 2. How many new substances are being formed in the liquid?

1. How does each differ from copper?

2. How does each differ from nitric acid?

Inf. 3. What are they formed from?

Why do you think so?

Inf. 4. Are the molecules of these new substances the same as those of the copper and nitric acid?

3. Why do you think so?

Inf. 5. Are the atoms the same?

Call a change in which the atoms of one or more substances combine in such a way as to form one or more new substances a *chemical change*.

Derive the term *chemical*.

Inf. 6. In the preceding experiment were the copper and nitric acid changed into nothing?

Inf. 7. What became of them?

4. What other chemical changes have you seen?

2. PHYSICAL CHANGE.

1. Were any new substances formed in the first experiment ?
2. How does the ninth differ from this ?
Call a change in matter in which no new substance is formed a *physical change*.
3. What kinds of changes have occurred in each of the other experiments performed ?

PHYSICS.

Call the knowledge of physical changes *Physics*.

Derive the terms *physics* and *physical*.

Call the knowledge of chemical changes

Write a connected description of the changes in matter, illustrating by experiments.

V. FORCE.

1. DEFINITION.

Call that which produces, or tends to produce, change *force*.

As to what this cause of change really is, we know nothing. We must infer that there is a cause, and we name it force.

Derive the word *force*.

2. PHYSICAL AND CHEMICAL

Inf. 1. The cause of a physical change would be called what kind of a force?

Inf. 2. The cause of a chemical change would be called what kind of a force?

It is also called *chemical affinity*.

Derive *affinity*.

1. It acts between what divisions of matter?

2. Physical forces act between what divisions of matter?

3. DIFFERENT FORCES.

a. MUSCULAR FORCE.

EXPERIMENT 10. (At home.)

Lift a chair, and hold it at arm's length.

Inf. 1. What produces this change?

1. By what was the force exerted?

Inf. 2. Infer a name for force so exerted.

2. Give other illustrations of the use of such force.

b GRAVITATION.

EXPERIMENT 11. (At home.)

Fill a wooden pail with water.

When the water has come to rest scatter a few blocks or chips of wood over its surface.

Obs. 1. Observe any change in the positions of the blocks.

Obs. 2. Let the pail stand for an hour, and observe the positions in which the blocks have come to rest.

Inf. Infer the cause of the change.

Where have you noticed similar results ?

EXPERIMENT 12. (At home.)

Hold a brick, or a stone as large as a brick, two or three feet from the ground, and let go.

Obs. State what happens.

Inf. Infer the cause.

EXPERIMENT 13. (At home.)

Place a brick upon the hand.

Obs. 1. Observe the effect.

Inf. 1. Infer the cause.

1. Upon what divisions of matter did the force manifested in the last three experiments act ?

2. In what directions with reference to each other did it draw the bodies ?

Call this force *gravitation*.

3. What, then, would you say that gravitation is ?

Derive *gravitation*.

GRAVITY.

4. In the last two experiments gravitation acted between what two bodies ?

5. Between the earth and what other bodies *have you found* that this force acts ?

Call the attraction between the *earth* and *bodies on or near its surface* *gravity*.

Derive the term.

6. What other name applies to this force ? (See question 2.)

7. Which is the more definite name ? Why ?

Inf. 2. Infer another name for a force which draws together.

Since it draws *masses* together it is called *molar attraction*.

Derive these words.

Obs. 2. If you fasten a string to a horse-chestnut and swing it so that it moves in the circumference of a circle, what is the effect upon the fingers ?

Obs. 3. If you let go the string, what happens ?

Inf. 3. This shows that a body moving in the circumference of a circle *tends* to move in what kind of a line ?

8. What other evidence of this tendency have you noticed ?

This tendency has been called *centrifugal force*.

9. Describe the tendency.

Derive *centrifugal*.

The earth and other planets move round the sun in nearly circular orbits.

Inf. 4. What prevents them from moving off in straight lines ?

c. COHESION.

Inf. 5. What would you call that which holds the *molecules* of a substance together ? (See *Inf.* 2.)

10. This force acts between molecules of the same kind, or of different kinds ?

Call the force which together *cohesion*.

Derive the word.

d. ADHESION.

EXPERIMENT 14. (At home.)

Insert your pencil in water, and withdraw it.

Obs. Observe the effect upon the pencil.

Inf. Infer the cause.

EXPERIMENT 15. (At home.)

Rub the lead of your pencil across a piece of paper.

Obs. Observe the effect upon the paper.

Inf. Infer what causes this.

1. Are the molecules of lead and paper alike ?

Call the force which holds molecules of different substances together *adhesion*.

Derive *adhesion*.

2. How does it differ from cohesion ?

3. In what do cohesion and adhesion agree ?

Hence the term *molecular attraction* is applied to both.

e. HEAT.

EXPERIMENT 16. (At home.)

Hold a piece of wax near the flame of a burning match.

Obs. Observe the effect upon the wax.

Call the force which causes this change *heat*.

f. LIGHT.

EXPERIMENT 17. (At school.)

Moisten a strip of paper four inches long in a solution of silver nitrate.

Shut one half of the paper between the leaves of a book, and leave the other half exposed.

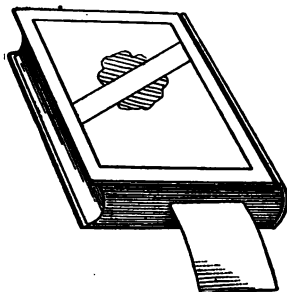


Fig. 6.

Place the book where the sun will shine upon the exposed half of the paper, and leave it there for ten minutes.

Obs. Observe the effect upon each half of the paper.

Inf. Infer what force produced the change.

g. MAGNETISM.

EXPERIMENT 18. (At school.)

Obs. Bring a magnet near to, or in contact with, pieces of copper, iron, zinc, lead, silver, steel, wood, and other substances, and observe the effect.

Inf. Infer what must have produced this effect.

Call this force *magnetism*.

Derive *magnet* and *magnetism*.

A. FRICTIONAL ELECTRICITY.

EXPERIMENT 19. (At home.)

Fold a piece of silk cloth into a pad five or six inches square.

Warm the pad, and also a straight lamp chimney or stick of sealing wax.

Obs. 1. Bring them successively near some small bits of paper, and see if they affect the paper.

Rub the chimney briskly with the silk, and repeat the experiment.

Obs. 2. State the effect.

Inf. 1. Infer the cause.

Inf. 2. Infer how this force was produced.

Call it *frictional electricity*.

Derive these words.

i. VOLTAIC ELECTRICITY.

EXPERIMENT 20. (At school.)

Into a tumbler two thirds full of water pour about one twelfth as much sulphuric acid.

Add as much potassium bichromate as will dissolve.

In this solution insert a plate of sheet copper and one of sheet zinc, each about 2×5 inches.

Obs. 1. Holding them so that they will not touch each other, observe the surfaces of the metals.

Obs. 2. Touch their outer ends together, and observe any action upon the surface of either or both.

Inf. 1. What kind of change is this?

Remove the plates, punch a hole near the top of each, and connect them by a piece of copper wire 16 inches long, as shown in Figure 7.

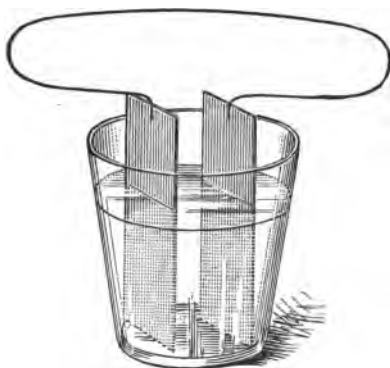


Fig. 7.

Obs. 3. Insert the plates in the solution, and see if there is any action upon the surface of either.

Remove the plates.

Magnetize a large needle or half a knitting needle, by rubbing the end of a magnet from one end of the needle to the other, always in the same direction.

Suspend this needle by a silk thread so that it will balance in a horizontal position.

When the needle has come to rest hold the wire connecting the plates parallel with the needle and just below it; and then just above it.

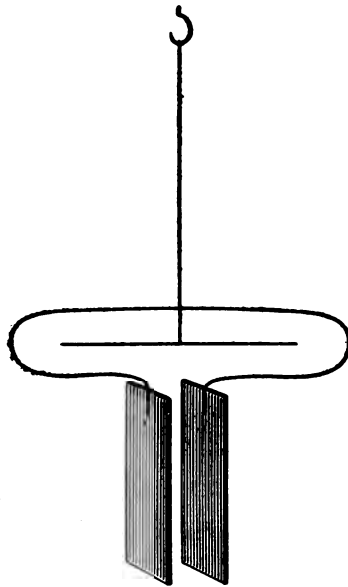


Fig. 8.

Obs. 4. Was the needle affected?

Insert the plates in the liquid in the tumbler, and hold the wire to the needle as before.

Obs. 5. State the effect.

Call the force which produces this change *voltaiic electricity*.

Inf. 2. How was it developed ? (See *Inf.* 1.)

Derive the term *voltaiic*.

1. Name the different forces which we have been considering.

2. Which of these act upon masses ?

Inf. 3. What kind of forces may you call them ?

3. Which act upon molecules ?

Inf. 4. What kind of forces may they be called ?

4. Which tend to bring bodies together ?

Gravitation has also been called *molar attraction*.

5. Which of these forces hold molecules together ?

6. What common name have you given to these forces ?

Write a connected description of the different forces studied, illustrating them by experiments.

4. CORRELATION OF FORCES.

EXPERIMENT 21. (At home.)

Touch a cent to your cheek.

Rub one side of it briskly against your sleeve for a few seconds, and touch it to the cheek again.

Obs. Observe any change.

Inf. Infer how it was produced.

1. What force was applied in the experiment ?

2. What force was developed by it ?

3. In what other cases have you noticed that heat was developed by friction ?

EXPERIMENT 22. (At home.)

Obs. 1. Examine a common match and see what it consists of.

The substance with which the tip is coated is a preparation containing phosphorus.

Rub the end of the match over a rather rough surface.

Obs. 2. Observe and state carefully what happens. Note the color of the flame, and any change in color.

Obs. 3. Bring your hand near the flame and observe the effect.

Inf. 1. Infer what force was developed by the rubbing?

1. What change immediately followed the rubbing?

Inf. 2. Infer what force must have caused the new combinations of matter.

Inf. 3. Did the heat aid or hinder the action of this force?

Inf. 4. What force is developed by the action of chemical affinity?

How do you learn this fact?

Inf. 5. What force is made to act by the action of *this* heat?

Inf. 6. How does the amount of heat developed by this chemical action compare with the amount used in starting the action?

2. State the order in which the different forces acted in Experiment 22, and the effect of each.

Inf. 7. In the use of a locomotive to move a train of cars what force acts first in the fire-box ?

Inf. 8. What force is produced by this action ?

Inf. 9. What effect does the heat in the water of the boiler have upon the train of cars ?

Call a force applied through a machine a *mechanical* force.

Derive the term.

3. The heat produced in the fire is here converted into what kind of force ?

4. Lightning is the action of what force ?

5. When it strikes a building what effect is often produced ?

Inf. 10. Infer what force must have been developed in order to produce this effect.

6. What changes of force occur here ?

Inf. 11. In producing electric light for towns what forces act, and in what order ?

Call this relation of forces by which one force may be converted into another *correlation of forces*.

Derive *correlation*.

Explain from illustrations, in writing, what is meant by correlation of forces.

5. MOLECULAR ATTRACTION.

1. What two forms of molecular attraction have we considered ?

Define each.

SOLUTION AND CRYSTALLIZATION.

EXPERIMENT 23. (At school.)

In two thirds of a tumbler of boiling water dissolve as much (powdered) alum as you can.

Suspend a small string over the middle of the tumbler, so that it will reach nearly to the bottom of the liquid.

Place the tumbler where it will not be disturbed, and allow the liquid to cool slowly.

Obs. Observe what forms upon the string, and upon the inside of the tumbler.

Potassium bichromate, copper sulphate, or iron sulphate may be used in place of the alum.

1. What state of matter was the alum?
2. What state of matter was the water?
3. What state of matter did the alum become in the hot water?

Call such a mingling of a solid with a liquid a *solution*.

The term solution is also applied to a mixture of a gas with a liquid, or to a mixture of two liquids.

Derive the term *solution*.

Inf. 1. What force must have acted to hold the molecules of alum and water together?

Inf. 2. What force must have been overcome in forming this solution?

4. What force was applied to aid the solution?
5. When this force disappeared what happened?

Inf. 3. What force must have acted to bring the molecules of alum together again?

Inf. 4. In this experiment does heat act with cohesion, or in opposition to it?

6. What kind of faces did the solids formed from this solution have?

Call solids having such faces and formed in this way *crystals*.

Define *crystals*.

Derive the term.

Call the process of forming them *crystallization*.

Derive *crystallization*.

CAPILLARY ATTRACTION.

EXPERIMENT 24. (At home.)

In a pan or plate containing a little water place two glass plates vertically, so that, with two of their vertical edges in contact, they will form a small angle.

Obs. 1. Increase and diminish the size of the angle, and observe the height of the water between the plates.

Inf. 1. Infer the cause.

Obs. 2. Oil the plates, and repeat the experiment.

Inf. 2. Observe and infer as directed.

EXPERIMENT 25. (At school.)

Insert small glass tubes of different sizes in water, in mercury, and in other liquids.

Obs. Observe the height of each liquid in the tubes.

Inf. Infer the cause of the difference observed.

1. The attraction manifest in Experiments 24 and 25 is between molecules of what states of matter?
2. What is its effect upon the liquid?

Call this form of adhesion *capillary attraction*.

Describe it.

Derive *capillary*.

ABSORPTION OF GASES.

EXPERIMENT 26. (At school.)

Obs. 1. Observe the odor of dilute ammonia water.

The odor is due to ammonia gas, which is mixed with the water and is gradually escaping from it.

Pour a little of this liquid into a test tube and add half as much powdered charcoal.

FILTER.

Fold a circular piece of filter paper (three or four inches in diameter) upon its diameter, and fold it again upon the radius at right angles to this diameter.

Open it at the circumference so as to make a hollow cone, and insert the apex in the mouth of a horse-radish bottle.

Pour the contents of the test tube into the paper cone.

Obs. 2. Observe what happens.

Call this apparatus a *filter*.

Call the liquid that passes through the paper a *filtrate*.

Obs. 3. Observe the odor of the filtrate and that of the charcoal.

Inf. 1. Infer the cause of the change.

The experiment may be repeated using hydrogen disulphide in place of ammonia.

Inf. 2. What does the charcoal do in these experiments?

Inf. 3. What force acts here?

From this peculiarity charcoal is used as a *deodorizer*.

Derive this term.

Inf. 4. Infer why a drop of oil on paper spreads over the paper.

1. Where does the oil of a lamp burn?

Inf. 5. Infer how it gets there.

6. MOLAR FORCE.

a. IMPULSIVE AND CONSTANT.

1. How does the force with which a bat strikes a ball compare in the length of time which it acts with the force which draws the ball to the ground?

Call a force which acts only for an instant an *impulsive force*.

Define.

Derive the term.

Call a force which acts continuously a *constant force*.

Define.

Derive *constant*.

2. What kind of force is the pressure of steam in a boiler ?
3. The attraction of two bodies for each other ?
4. Force applied by a blow ?

b. TENDENCY OF FORCE.

EXPERIMENT 27. (At home.)

Obs. Toss a ball gently upward, and observe carefully any change in the motion.

Inf. 1. What produced the motion ?

Inf. 2. What caused the changes in it ?

1. Does molar force *always* produce motion or change of motion ?
2. Give an instance in which muscular force does not produce either.
3. Give an instance in which gravity does not produce either.

Inf. 3. What is the *tendency* of molar force ?

c. VELOCITY OF MOTION.

1. How fast does a train of cars go ?

2. How fast does a man walk ?

Inf. 1. Call the rate of motion of a body its

Derive the term.

We say that a horse goes eight miles an hour.

3. What is an hour ?

4. What is eight miles ?

5. What did we state in giving the velocity of the train of cars ?

UNIFORM, VARIABLE, ACCELERATED, RETARDED.

6. How do the distances which the earth turns in successive hours compare ?

Call such a rate of motion *uniform* velocity.

7. What is uniform velocity ?

Derive *uniform*.

8. When a train of cars is getting under way, or when it is just coming to a stop, how do the distances passed in successive seconds compare ?

Call a rate of motion at which a body passes over a different distance in each successive unit of time *variable* velocity.

9. Define variable velocity.

Derive *variable*.

10. Define *accelerated* velocity.

Derive the term.

11. Define *retarded* velocity.

Derive *retarded*.

12. Give examples of uniform velocity.

13. Give examples of accelerated velocity.

14. Give examples of retarded velocity.

Inf. 2. What kind of velocity is produced by an impulsive force acting alone ?

Inf. 3. By a constant force acting alone ?

Inf. 4. By an impulsive and a constant force acting together in opposite directions ?

Think of a body thrown upward.

d. MOMENTUM.

EXPERIMENT 28. (At home.)

Roll a marble slowly upon the floor or oil-cloth.

Roll it twice as fast.

Think how much motion of matter there is in a second in the first case, and how much in the second case.

1. Compare the quantity of motion in a second in the first case with that in the second case.

Call the quantity of motion of a body in a given time its *momentum*.¹

Derive *momentum*.

Inf. Infer one thing upon which the momentum of a body depends.

EXPERIMENT 29. (At home.)

Roll a small marble, and then roll one two or three times as heavy at the same rate.

1. Compare the movements of matter in a second in those two cases.

Inf. Infer another thing upon which momentum depends.

e. INERTIA.

Inf. 1. Could a moving body ever change its velocity or direction of motion unless acted upon by some force?

¹ The term *momentum* has sometimes been used to mean the force with which a moving body tends to overcome resistance and move on.

Call the inability of a moving body to change its motion *inertia of motion*.

Define.

The term *inertia* is also used in the sense of the *tendency* of a body at rest to remain at rest, or of a body in motion to continue the motion.

Derive *inertia*.

Inf. 2. Call the inability of a body at rest to move *inertia of*

Define.

A man stood on the bow of a boat when it struck a hidden rock.

Inf. 3. Infer what happened, and why.

Inf. 4. Why is it dangerous to step from a moving carriage or car?

Inf. 5. How may it be done most safely?

Inf. 6. An electric car started suddenly, and many of the standing passengers were

Inf. 7. Why?

Inf. 8. Why does a train of cars start slowly and acquire speed gradually?

Inf. 9. Why can it not be stopped suddenly?

1. What is the effect when two rapidly moving trains meet upon the same track? Why?

2. In driving a nail with a hammer what is the force as it is applied to the nail?

Inf. 10. How is the dust removed from a carpet by beating?

f. RESISTANCE.

OF THE AIR.

EXPERIMENT 30. (At home.)

Move a fan edgewise quickly through the air.

Obs. Move it at the same rate in the usual way, and observe any difference in the force required.

Inf. 1. Infer what causes this difference.

Call that which hinders motion *resistance*.

Define.

Derive *resistance*.

Call the resistance in this experiment *resistance of the air*.

Inf. 2. It is really due to what property of the air?

OF INERTIA.

Inf. 3. To what is the greater part of the resistance in starting a train of cars due?

Call it *resistance of inertia*.

Inf. 4. What does the amount of this resistance depend upon?

OF FRICTION.

EXPERIMENT 31. (At home.)

Tie one end of a string around a book.

Obs. Holding the other end in the fingers, draw the book by the string slowly and with uniform motion over the carpet, and notice whether any force is required after inertia has been overcome.

Inf. Infer why this force is required.

Call this resistance the *resistance of friction*.

Derive this term.

OF MUSCULAR FORCE.

EXPERIMENT 32. (At home.)

Obs. Repeat Experiment 31, pressing with the fingers of the other hand slightly against the forward end of the book, and observe any difference in the force required to move the book.

Inf. Infer what this difference is due to.

OF GRAVITY.

EXPERIMENT 33. (At home.)

Raise the book vertically by the string.

Inf. 1. What is the resistance chiefly due to?

Inf. 2. If the book weighs two pounds and you lift with a force of three pounds, what becomes of the surplus force which gravity does not resist?

Inf. 3. How much of this surplus will be used up in that way?

Inf. 4. How, then, does the sum of all the different forms of resistance compare with the force resisted?

Inf. 5. How does the direction of the resistance compare with that of the moving force?

Newton has expressed these facts by saying that *action* and *reaction* are *equal* and in *opposite directions*.

Inf. 6. What can he mean by *action* and *reaction*?

g. MEASURE OF FORCE.**EXPERIMENT 34. (At school.)**

Make a spring of No. 22 brass wire by winding it closely upon a pencil.

Cut the string used in Experiment 31 between the book and the end held in the fingers, and fasten the ends thus made to the ends of the spring.



Fig. 9.

Obs. 1. Repeat Experiment 31, and ascertain by a rule how much the spring is stretched.

Obs. 2. Draw the book over the smooth surface of a table, and see how much the spring is stretched.

Inf. 1. Compare carefully the forces used in the two parts of this experiment.

1. What is the *unit* used in the measure of gravity? Other molar forces are measured by the same unit.

EXPERIMENT 35. (At home.)

Make a one-pound, a two-pound, and a five-pound weight, by weighing out the right quantities of pebbles in tin cans.

Lift these weights successively, and note the force required in each case.

1. Compare a force that will sustain one pound with one which will support two pounds; with one which will support five pounds.

A. WORK.

Inf. 1. What forms of resistance must be overcome in drawing a double-runner up hill?

Call the overcoming of resistance of any kind *work*.

Inf. 2. *a.* How does the work of raising a pound one foot compare with the work of raising it four feet?

b. With that of raising it ten feet?

c. With that of raising two pounds two feet?

d. With that of raising three pounds ten feet?

1. What two things must be considered in measuring work?

2. What is the unit of work with which we have compared the work in each of these cases?

Call this unit a *foot-pound*.

Define.

3. How many foot-pounds of work in each of the above cases?

i. POWER.

Inf. 1. Which can do more work in an hour, a horse or a locomotive?

The *rate* at which an agent can do work is spoken of as its *power*.

Define.

Inf. 2. In measuring power what must we consider besides units of work done?

One *foot-pound* of work in a *second* is a unit of power.

In measuring the power of agents capable of doing a large amount of work 550 foot-pounds of work in a second is taken as the standard. This is called a *horse-power*.

Define.

An engine of one horse-power is capable of acting through one foot in a second against a resistance of 550 pounds, or of acting through 550 feet in a second against a resistance of one pound.

1. How far can it raise 275 pounds in a second?
2. How far can it raise 1100 pounds in a second?
3. How far can it raise 1100 pounds in ten seconds?
4. How many pounds can a twenty horse-power engine raise ten feet in a second?

j. ENERGY.

Inf. Think how it is that a *moving body*, a *bent* or *coiled spring*, or a *lifted weight* can do work.

Call the ability to do work *energy*.

Define.

Derive the term.

k. COMPOSITION OF FORCES.

From a strip of sheet lead, cut three pieces an inch square, two pieces 1×2 inches, two pieces 1×3

inches, two pieces 1×4 inches, and two pieces 1×6 inches; and make a hole with an awl through one corner of each piece.

Make a wooden frame two feet long and sixteen inches high, and attach two small pulleys to the top of the frame a foot apart, as shown in Figure 10.

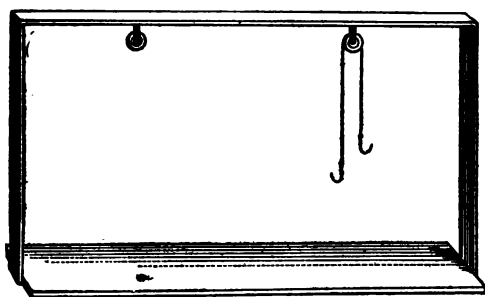


Fig. 10.

Equilibrium.

EXPERIMENT 36. (At school.)

Pass a short string over one of the pulleys and tie a hook made of a bent pin to each end of it.

Hang a strong envelope upon one hook, and upon the other hang an inch lead and a two-inch lead.

Pour into the envelope as much sand as the two leads will balance.

When all the forces acting upon a body balance each other, it is said to be in *equilibrium*.

Derive the term.

Resultant.

1. Do the two leads act in the same or in different lines ?

2. In the same or in opposite directions ?

Obs. Find a single force which will produce the same effect as these two.

Call it a *resultant* of the two.

Define.

Derive *resultant*.

Components.

Call the original forces the *components* of the resultant.

Define. (A force may have more than two components.)

Derive the term *components*.

Two Forces in Same Line.

IN SAME DIRECTION.

Inf. 1. Resultant of two forces acting in same line in same direction equals what ? (See *Obs.*, above.)

Acts where ? and in what direction ?

Suppose a boat is rowed down stream at the rate of four miles an hour, and the current carries it two miles an hour.

Inf. 2. With what velocity does it proceed ?

IN OPPOSITE DIRECTION.

EXPERIMENT 37. (At school.)

Pass the string over the pulley, and hang a two-inch lead on one end and a six-inch lead on the other.

Hang an envelope on the hook with the lighter weight, and pour into it sand enough to produce equilibrium.

Obs. Remove the two lead weights, and find their resultant, and apply it.

1. This is the resultant of what ?

2. It equals what ? acts where ? in what line ?

A boat sails through the water at the rate of eight miles an hour against a current of three miles an hour.

Inf. 1. What is its actual rate of progress ?

A steamer propelled by a force that would carry her ten miles an hour is held back by a wind that, acting alone, would carry her astern at the rate of four miles an hour.

Inf. 2. How long will it take her to go twenty-eight miles ?

Two Parallel Forces.

IN SAME DIRECTION.

EXPERIMENT 38. (At school.)

On the same side of a light wooden bar thirteen inches long place two small screw-eyes twelve inches apart.

On the opposite side of the bar insert three more screw-eyes at intervals of three inches from the first and from each other.

Pass cords from the end screw-eyes over the pulleys, in the frame used in Experiment 36, and balance

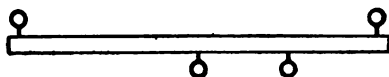


Fig 11.

the bar in a horizontal position by small weights on the cords.

Obs. On one of these cords hang a two-inch lead, and on the other a six-inch lead; and find what weight they will balance, and where it must be placed to keep the bar horizontal.

Inf. 1. From this infer what the resultant must be.

A force of 100 pounds and a force of 200 pounds act in parallel lines in the same direction.

Inf. 2. Their resultant is a force of pounds acting in the direction, in a line as far from the line of the greater force as from that of the smaller.

Two Forces at an Angle.

A boat is rowed across a river at the rate of six feet a second, and carried down stream by the current at the rate of three feet a second.

1. Draw a line on paper, starting from a given point *a*, to represent the direction in which the boat would have moved and the distance which the rowing would have carried it in three seconds without any current, and mark the end *b*.

Draw another line, starting from the same point, to show in what direction and how far the current would have carried it without the rowing, and mark the end c .

Consider the rowing and the current as acting at the same time.

How far across the river and how far down the river will it have been carried in twenty seconds?

Mark its actual position at the end of that time d .

Draw a line showing the actual path in which the boat has moved.

Connect d with b and c by straight lines.

2. What figure have you drawn?
3. What does the diagonal represent?
4. What do the sides ab and ac represent?

Inf. Infer how the resultant compares with the sum of the components, and with the difference of the components.

5. How does its direction compare with the directions of the components?

VI. GRAVITY.

1. Recall *definition* and *derivation* of gravity.

2. CENTRE OF GRAVITY.

EXPERIMENT 39. (At home.)

Suspend a weight from a fixed point by a thread about twelve inches long, with a small loop in the thread just below the point of support.

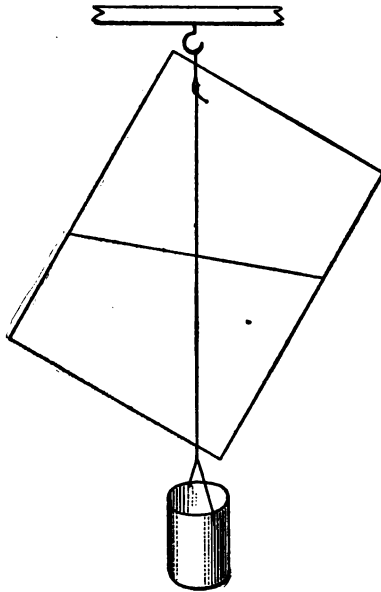


Fig. 12.

Stick a pin through a piece of card-board near one edge, and hang it in the loop so that the thread will be in front of the card-board.

Mark upon the card-board the position of the thread below the loop.

Stick the pin through some other part of the card-board near the edge, hang it in the loop, and mark as before.

Place the intersection of these marks on the point of a pin, and see if it will balance in different positions.

If not, repeat the experiment, taking care to mark the positions of the thread exactly.

Call the point at which a body may be supported in any position its *centre of gravity*.

Define.

3. LINE OF DIRECTION.

Call the line passing through the centre of gravity of a body and the centre of the earth the *line of direction* of the body.

Define.

4. EQUILIBRIUM.

a. OF A BODY SUPPORTED AT ONE POINT.

EXPERIMENT 40. (At home.)

Stick a pin through the card used in Experiment 39, at its centre of gravity, and pin it against a vertical surface so that it will turn easily on the pin.

Obs. 1. In what positions is it in equilibrium?

Obs. 2. In the same way support the card an inch from the centre of gravity, and find in what positions it is in equilibrium.

STABLE EQUILIBRIUM.

Obs. 3. In what direction from the centre of gravity is the support when the greatest force is required to overturn the body ?

Inf. 1. Why is more force required to disturb the equilibrium with the body in this position ?

A body so supported is said to be in *stable equilibrium*.

Derive *stable*.

UNSTABLE EQUILIBRIUM.

Obs. 4. In what direction from the centre of gravity is the support applied when least force is required to overturn the body ?

Inf. 2. Why is less force required with the support applied there ?

A body so supported is said to be in *unstable equilibrium*.

Derive *unstable*.

NEUTRAL EQUILIBRIUM.

Obs. 5. Where is the support applied when the body is balanced in any position ?

A body so supported is said to be in *neutral equilibrium*.

Derive *neutral*.

b. OF A BODY RESTING ON ITS BASE.

1. In what position is a book in most stable equilibrium ?

Inf. 1. In what position of the book will the centre of gravity have to be raised most to overturn it ?

Inf. 2. In what position of the book would the centre of gravity have to be raised least to overturn it?

Inf. 3. Is a tall body more or less stable than a short body? Why? (See *Inf.* 1 and 2.)

Inf. 4. Is a body with a large base more or less stable than one with a small base? Why?

Inf. 5. Through what point of the base must the line of direction pass that the body may be as stable as possible?

Inf. 6. Will a body stand if the line of direction passes outside the base?

Inf. 7. The stability of a body resting on its base depends upon what?

Inf. 8. Why are legs of chairs and stools made to slant outward?

A young lady placed a step ladder in the position shown in Figure 13, and it stood.



Fig. 13.

Inf. 9. Infer where the line of direction passed with regard to the base.

The young lady proceeded to mount the steps.

Inf. 10. Infer what happened, and why.

5. FALLING BODIES.

Inf. 11. What causes bodies to fall?

1. What kind of a force is gravity?

Inf. 12. Infer with what kind of velocity a body will fall?

EXPERIMENT 41. (At home.)

Obs. Get some one to drop a body from an elevated position, and, standing at a little distance, observe the rate of fall carefully.

1. Does your observation agree with your inference?

6. PENDULUM.

a. DEFINITIONS.

EXPERIMENT 42. (At home.)

By means of a thread suspend a light weight from a fixed point, so that the centre of gravity of the weight will be eighteen inches from the point of support.

Obs. Pull the weight aside; let go, observe the effect, and describe it carefully.

Call a body suspended from a fixed point so as to swing freely a *pendulum*.

Define.

Derive *pendulum*.

Call one swing of a pendulum a *vibration*.

Define.

Derive *vibration*.

b. CAUSE OF VIBRATION.

Inf. Infer what causes a pendulum to vibrate.

c. RATE OF VIBRATION.

EFFECT OF LENGTH OF ARC.

EXPERIMENT 43. (At home.)

Obs. 1. Pull the pendulum three inches aside, let go, and count the vibrations for thirty seconds.

Obs. 2. Pull the pendulum six inches aside, let go, and count the vibrations for thirty seconds.

Inf. Infer whether the rate of vibration is affected by the length of arc through which the pendulum swings.

EFFECT OF WEIGHT OF PENDULUM.

EXPERIMENT 44. (At home.)

Obs. Suspend a heavier weight so as to make a pendulum of the same length, and see how many vibrations it will make in thirty seconds.

Inf. Infer whether the weight of the pendulum affects the rate of vibration.

EFFECT OF LENGTH OF PENDULUM.

EXPERIMENT 45. (At home.)

Obs. 1. Lengthen the pendulum and see how the rate of vibration is affected.

Obs. 2. Make the pendulum four times as long as at first, and see how the rate of vibration is affected.

EXPERIMENT 46. (At home.)

Obs. 1. By trial find a pendulum of such length that it will make one vibration a second.

How long is it ?

Obs. 2. Find a pendulum that will vibrate half-seconds.

How long is it ?

USE OF THE PENDULUM.

1. How does the number of vibrations made by a pendulum in one minute compare with the number made in any other minute ?

2. How then, would you say the pendulum vibrates ?

3. By reason of this fact it is adapted to what use ?

Describe its use as a metronome.

Derive *metronome*.

USE IN CLOCKS.

EXPERIMENT 47. (At school.)

Wind a clock, and start it. Notice how it goes for a minute or two.

Obs. Remove the hands and face of the clock, and observe how the pendulum is connected with the works.

Inf. 1. What is the tendency of the coiled spring?

Inf. 2. What is the relation of the spring to the works?

Inf. 3. Infer what would happen if there were no pendulum?

Inf. 4. Infer the use of the pendulum.

7. PRESSURE OF LIQUIDS.

a. FACT OF PRESSURE.

EXPERIMENT 48. (At school.)

Over the large end of a small lamp chimney tie a piece of sheet rubber such as may be obtained of a dentist.

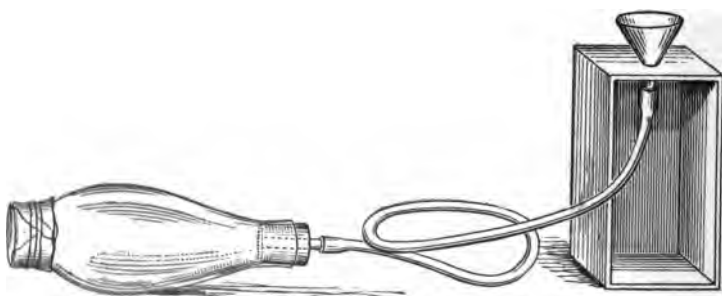


Fig. 14.

Fit a cork stopper water-tight into the small end of the chimney.

Perforate the cork near one side with a rat-tail file, and fit tightly a short glass tube.

Over the end of this tube draw one end of a piece of rubber tubing about two feet long.

Draw the other end of this tubing over the tube of a small tunnel supported by means of a crayon box or stand, as in Figure 14.

Loosen the stopper a little so that air may escape, and pour into the tunnel water enough to fill the chimney, the tube, and the tunnel; and press the stopper in tight.

Obs. 1. Observe the effect upon the sheet rubber.

Inf. 1. Infer the cause of this.

b. DIRECTIONS OF PRESSURE.

Obs. 2. Keeping the sheet rubber at the same distance below the level of the surface of the water in the tunnel, turn the chimney so that it will be horizontal, and observe the effect upon the sheet rubber.

Do not claim to *observe* what you *infer*.

Inf. 2. What causes this?

Obs. 3. Keeping the rubber at the same level, turn the chimney so that the rubber will be upward, and observe.

Inf. 3. Infer the cause.

Inf. 4. In what directions does water at rest press?

c. UPON WHAT PRESSURE DEPENDS.

EXPERIMENT 49. (At school.)

Obs. Slowly lower the chimney farther below the level of the surface of the water, and observe the effect upon the sheet rubber.

Inf. What does pressure of a liquid at rest depend upon? i. e. how does it vary?

EXPERIMENT 50. (At school.)

In the gas or alcohol lamp flame, heat a piece of small glass tubing about two inches from the end, and when it becomes soft draw it out to a point.

When it is cooled, break off the small end of the two-inch piece, so as to leave an opening about one sixteenth of an inch in diameter.

Fit the large end of this tube into the cork stopper in the end of the chimney.

Obs. 1. Fill the chimney, tube, and tunnel with water, and observe what the water does.

Obs. 2. Lower and raise the chimney, and observe the effect.

Inf. Infer the cause of this action.

d. SURFACE OF LIQUID IN COMMUNICATING VESSELS.

EXPERIMENT 51. (At school.)

Remove the short glass tube from the cork, and insert one about two feet long.

Obs. 1. Holding the chimney and this long tube upright, fill the chimney, rubber tube, and tunnel with water, and observe the height of the water in the glass tube.

Obs. 2. Slowly raise and lower the tunnel, and compare the height of the water in the glass tube with its height in the tunnel.

e. WATER WORKS FOR CITIES AND TOWNS.

Describe with diagrams the water works of your city or town, representing the *pumping station, stand-pipe or reservoir, mains, hydrants, and pipes in a house.*

Inf. 1. Where is the pressure in the pipes greatest ?

Inf. 2. How high will water rise in the pipes ?

Inf. 3. Where would water be thrown highest from a hose connected with a hydrant ?

f. THE SPIRIT LEVEL.

Examine a spirit level.

Obs. 1. Of what parts does it consist ?

The liquid in the tube is alcohol, and the bubble is air.

Inf. Why is alcohol better than water ?

Obs. 2. When the bubble is in the middle of the tube, what is the position of the case ?

1. How is the level used ?

g. SPRINGS AND WELLS.

What becomes of the water that falls upon the land as rain ?

The portion of it which sinks into the ground works down through soil, loam, sand, or gravel, and comes to a layer of material, $a\ a'$, in the diagram, through which it does not readily pass.

It works its way along the slope of this impervious layer, through the loose material which rests upon it, and may reach the surface at some lower level, as at a' .

Call the water flowing out at the surface a *spring*.

Suppose the water fills the loose material to the level $c c'$.

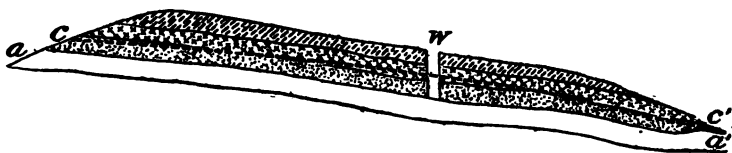


Fig. 15.

Inf. 1. If a hole is dug down through this material, as at w , what will fill the lower part of the hole?

Inf. 2. To what level?

Call such a hole extending down below the level of the water in the earth a

ARTESIAN WELLS.

Sometimes a layer of loose material, as $s s'$, included between two layers of earth impervious to water, is exposed at the surface along one edge, as

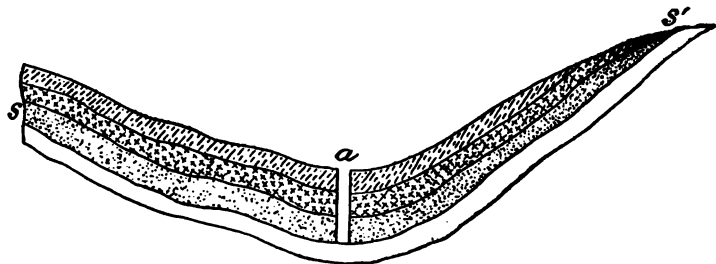


Fig. 16.

at s' , and stretches down an extended slope, perhaps for many miles.

The exposed portion of this layer may cover a large area.

What will become of the water which falls upon this exposed portion of the stratum?

Suppose a hole be bored through the close layer above at some lower point, as at *a*.

Inf. 1. Infer what the effect would be.

Call such a well an *Artesian well*.

Derive this name.

Inf. 2. What force acts to produce springs and wells?

A. FLOATING AND SINKING.

EXPERIMENT 52. (At school.)

Upon a convenient support four or five feet from the floor hang the spring balance, so that it will not be within four or five inches of a wall.

Upon the hook of the balance hang a quart tin pail, and observe its weight.

Below the pail suspend a pebble a little smaller than the pail and observe its weight.

Set another pail, large enough to contain the pebble, in a basin, and fill this pail just full of water. Holding the balance in the hand, lower it until the pebble is covered with the water.

Obs. 1. Observe what happens to the water and to the spring.

Inf. 1. Infer how large a volume of water is displaced.

Inf. 2. Has the pebble gained or lost in weight by being immersed in the water? How much?

Obs. 2. Remove the pail from the basin, and, again holding the balance so that the pebble is immersed, pour the water from the basin into the empty pail, and notice the effect upon the balance.

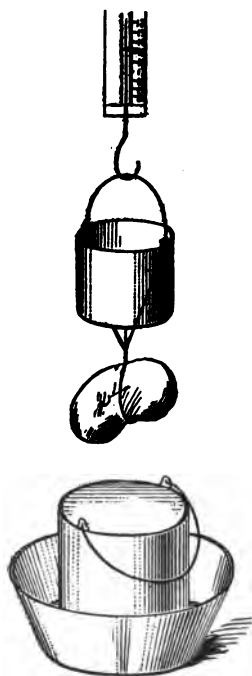


Fig. 17.

Inf. 3. How does the weight of the pebble in water, together with the weight of the water displaced, compare with the weight of the pebble in air?

Repeat this experiment using a mass of iron in place of the pebble.

Inf. 4. How does the loss of weight of a solid immersed compare with the weight of an equal volume of the liquid?

Inf. 5. A solid having the same weight as its own volume of the liquid will lose how much of its weight on being immersed?

Inf. 6. Will it float, or sink?

Inf. 7. If it will float, at what level?

Inf. 8. Will a body heavier than water float in water, or sink?

Inf. 9. Will a body lighter than water float, or sink?

Inf. 10. Will it project above the liquid?

Inf. 11. A body half as heavy as water will float with what part of it above water?

Inf. 12. Since a piece of sheet tin or of iron sinks in water, how can a tin pan or an iron ship float?

i. SPECIFIC GRAVITY.

OF SOLIDS.

Divide the weight of the pebble in air, in the preceding experiment, by the weight of an equal volume of water.

Call the quotient the *specific gravity* of the pebble.

Derive the term.

Find the specific gravity of a mass of iron weighing two or three pounds.

- a. Think how you can find the weight of an equal volume of water.
- b. Think how you can proceed to find the specific gravity of the iron.
- c. Find it.
1. State how to find the specific gravity of solids heavier than water.

Inf. 13. Suppose a body floats with half of its volume under water, what is its specific gravity?

Inf. 14. If it floats with an eighth of its volume under water, what is its specific gravity?

Inf. 15. If a body floats with five sixths of its volume out of water, what is its specific gravity?

A convenient spring balance for finding the specific gravity of small specimens of minerals and metals may be made as follows.

Cut out a piece of board (pine or white wood) about 6 inches square, and another piece about 16 inches long, and $1\frac{1}{2}$ inches wide at one end and 1 inch at the other end.

Nail the wide end of this strip to the middle of one edge of the square, so that it will stand upright with the square as a base, as shown in the figure.

Near the top of this standard insert horizontally a screw-eye of small wire $1\frac{1}{2}$ inches long, with eye opened so as to form a hook.

Make a spring by winding brass wire, No. 25 to 28, close about a pencil, and keeping it wound for a minute or two.

Hang the spring by one end of the coil upon the hook.

Bend the end of the wire at the lower end of the coil into a horizontal position, so that it will project as an index in front of the standard.

Mark off a scale upon this standard from the level of the index downward, by drawing horizontal lines $\frac{1}{16}$ of an inch apart and numbering every fifth line.

By means of a noose of horse hair or fine thread, suspend the specimen from the lower end of the spring, and see how many degrees it stretches the spring, i.e. how many units of weight it has.

Raise a tumbler partly filled with water under the specimen until it is immersed, and thus get its loss of weight in water.

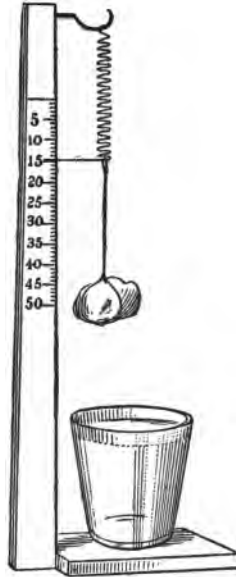


Fig. 18.

OF LIQUIDS.

EXPERIMENT 53. (At school.)

1. Weigh a small-mouthed bottle.
2. Fill it with water and weigh it.
3. Fill it with saturated brine and weigh it.
4. Find the specific gravity of the brine.
5. Find the specific gravity of alcohol, of linseed oil, and of kerosene.

8. PRESSURE OF AIR.

a. FACT OF PRESSURE.

EXPERIMENT 54. (At school.)

Over the mouth of a T. D. clay pipe, tie, air-tight, a piece of sheet rubber.

Obs. 1. Taking the stem of the pipe in the mouth, with the bowl upright, "draw out" through the stem as much air as you can, and observe the effect upon the sheet rubber.

Inf. 1. Infer what causes this effect.

b. DIRECTIONS OF PRESSURE.

Obs. 2. Turn the bowl of the pipe downward, draw out the air, and observe the effect.

Inf. 2. Infer the cause of this.

Repeat this with the bowl in various positions.

Inf. 3. In what directions does the air press?

c. EFFECTS OF PRESSURE.

EXPERIMENT 55. (At home.)

Fill a tumbler with water, cut a piece of card-board a little larger than the top of the tumbler, and lay it over the top.

With the palm of the hand hold it against the edge of the tumbler without pressing the middle of it in, invert the tumbler, and remove the hand.

Obs. Observe the effect.

Inf. Infer why the water does not fall out.

EXPERIMENT 56. (At school.)

Insert a small glass tube in water, and note the height of the water in the tube.

Place the thumb over the top, and raise it vertically out of the water.

Obs. Observe whether the water remains in the tube.

Inf. Infer the cause.

EXPERIMENT 57. (At home.)

Fill a tumbler with water, invert it under water, and, holding it even, raise it until the mouth is nearly even with the top of the water.

Obs. Observe the height of the water in the tumbler.

Inf. 1. What sustains the water there?

Inf. 2. What force causes the pressure of the air?

BAROMETER.

EXPERIMENT 58. (At school.)

By means of a short piece of rubber tubing, connect the tube of a small glass tunnel with one end of a heavy glass tube 33 or 34 inches long, and closed at the other end.

Fill the tube with mercury.

If there are air bubbles in the tube, remove them by inserting a slender iron wire.

Holding the finger firmly over the end of the tube,

so that no mercury can run out, invert the tube, and insert the open end of it in a cup of mercury.

Obs. 1. Notice the height of the mercury in the tube.



Inf. 1. Why does it not all run out of the tube?

Inf. 2. Why does it not entirely fill the tube?

Obs. 2. Measure the height of the mercury in the tube above the surface of the mercury in the cup.

It is found by experiment that the height of the column of mercury is *not affected* by the *size* of the tube, but *varies slightly* for *all tubes* at different times.

Inf. 3. What does the height of the mercury column depend upon? (See *Inf.* 1 and 2.)

Inf. 4. What does the variation in the height of the mercury indicate?

Thus the height of the mercury column becomes a *measure of the atmospheric pressure*.

For this use the tube is attached to a case with a graduated scale at the top to indicate the height of the mercury column in inches; and the whole apparatus is called a *barometer*.

Describe it, and derive the name.

EXPERIMENT 59. (At school.)

Place the barometer where it will not be disturbed, and note the changes in the height of the mercury and the changes in the weather for a few weeks.

Obs. What correspondence in these changes can you discover ?

Inf. What inferences in regard to the weather can you make from changes in the barometer ?

PUMPS.

LIFTING PUMPS.

EXPERIMENT 60 (At school.)

Into an even glass tube fit a piston with a rod a little longer than the tube.

Holding the tube in the left hand, push the piston through the tube so that it will be even with the end of the tube.

Obs. Holding this end steadily under water, slowly raise the piston, and observe the effect in the tube.

Inf. What causes this ?

If you have a glass lifting pump, or can buy one, use it. If not, a good one may be made by careful work.

TO MAKE A LIFTING PUMP.

Fit two small screw-eyes with rather long screws into the end of a spool 1 inch or $1\frac{1}{8}$ inches in diameter, as shown in Figure 20.

Cut out a piece of sheet rubber $\frac{1}{2} \times \frac{3}{4}$ of an inch; lay one end of this upon the flat surface of a block of pine $\frac{1}{2} \times \frac{1}{2} \times \frac{3}{8}$ of an inch, and fasten it to the block by a single small tack in the centre. (See Figure 20.)

Lay this block, rubber-side down, over the hole in the end of the spool between the screw-eyes; and with two small tacks fasten the projecting portion of the rubber to the end of the spool, so as to form a little valve opening from the spool and covering the hole in the spool when closed.

Get a piece of pine 10 inches long and $\frac{1}{2}$ inch square at one end, and at the other end $\frac{1}{4}$ inch thick and wide enough to fill the space between the screw-eyes.

Place the wide end of the rod between the screw-eyes, and fasten it by small screws passing through the screw-eyes, taking care to have the end of the rod far enough from the spool to allow the valve to open at least $\frac{1}{4}$ of an inch.

Round off the rod with a knife, and wind upon the spool enough twine to a little more than fill it.

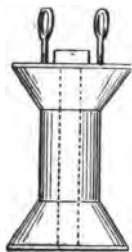


Fig. 20.



Fig. 21.

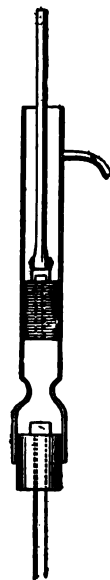


Fig. 22.

Call this apparatus the *piston* of your pump.

Select a lamp chimney such as is shown in Figure 21, of the same diameter throughout the straight part.

To test the evenness of chimneys fit the piston into them and work it carefully up and down, noticing whether the fit is equally close throughout.

Fit tightly a cork into the large end of the chimney.

Perforate this cork with a rat-tail file, and fit a glass tube 8 or 10 inches long into it water-tight, as shown in Figure 22.

Make a valve covering the top of this tube like the valve in the top of the piston.

Insert the cork into which the tube has been fitted in the large end of the chimney.

With a triangular file make a hole through the side of the chimney about 2 inches from the top, then with a rat-tail file round out the hole so as to make it elliptical, and insert in it a short piece of rubber tube for a spout.

EXPERIMENT 61. (At school.)

Having made sure that the piston and the cork are tight, take the chimney in the left hand and the piston rod in the right, and inserting the glass tube below the surface of the water, carefully work the piston up and down.

Obs. 1. Observe the position of each valve as the piston is raised, and as it is lowered.

If no change is observed, work the piston faster, and notice carefully.

Inf. 1. Infer the cause of the changes.

Obs. 2. Observe the change in the water.

Inf. 2. Infer the cause of this change.

NOTE. — To say that the water is “drawn up,” or “sucked up,” is not giving any *cause*.

If a pipe 33 feet or more in length, closed at one end and open at the other, be filled with water, and, with the open end kept under water, the closed end be raised until it is brought to a vertical position, it has been found that the water will continue to fill the pipe to the height of about 32 feet above the level of the water outside of the pipe.

Inf. 3. Infer what keeps the water up to that height.

Inf. 4. Why does it not sustain a higher column of water?

Inf. 5. About how high should you think water could be raised with a lifting pump?

Is it ever necessary to raise water higher than that?

FORCE PUMP.

TO MAKE A FORCE PUMP.

Fit a rod about 10 inches long into a spool 1 inch in diameter, as in Figure 23. Wind the spool full of twine, and select a lamp chimney of even bore, as for the lifting pump.

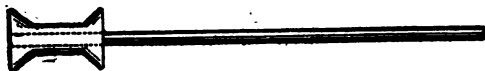


Fig. 23.

Fit the bottom of the chimney tightly with a firm cork, and fit the cork with a tube and valve, as in the lifting pump.

Fit tightly a firm cork into a horse-radish bottle.

Connect the lower part of the chimney with the bottle by a glass tube, bent as shown in Figure 24, and fitted tightly into the stoppers.

Over the end of this tube in the bottle place a valve like that in the chimney.

Make another hole in the cork in the bottle and fit into it tightly a glass tube 5 or 6 inches long, bent as shown in the figure, and drawn out to a small size at the end *b*, Figure 24.

EXPERIMENT 62. (At school.)

Having made sure that the piston, corks, and tubes are all tight, hold the chimney in the left hand, insert

the tube *a* under water, and work the piston carefully with the right hand.

Obs. 1. Observe the action of each valve and the movement of the water as the piston is raised and as it is pressed downward.

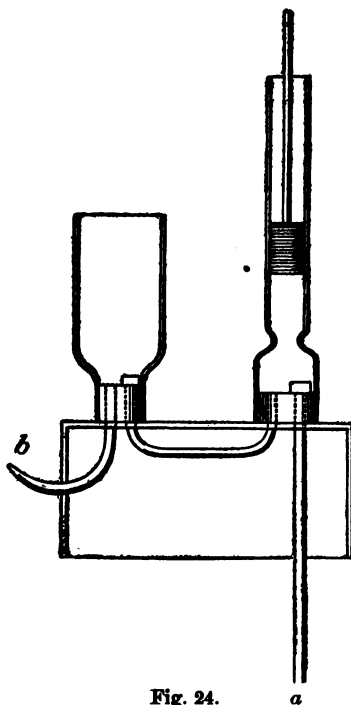


Fig. 24.

Inf. 1. Infer the cause of each change observed.

Obs. 2. What is in the upper part of the bottle? Call the bottle an *air-chamber*.

Inf. 2. Of what advantage is it?

Inf. 3. What kind of pump is used at a pumping station?

1. What do fire-engines for throwing water consist of?

Write a connected description of each kind of pump, illustrating by drawings.

VII. SIMPLE MACHINES.

1. LEVERS.

a. DEFINITIONS.

LEVER.

EXPERIMENT 63. (At home.)

Place a pencil or rule upon a book so that one end of it will project about 3 inches beyond the edge of the book.

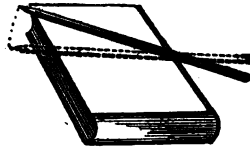


Fig. 25.

By raising and lowering the ends of the pencil, turn it about the edge of the book as a fixed support.

Call a bar so arranged a *lever*.

Define.

Derive the term.

FULCRUM.

Call the support upon which it turns the *fulcrum* of the lever.

Define.

Derive *fulcrum*.

LOAD AND POWER.

EXPERIMENT 64. (At home.)

Place another book upon the projecting end of the lever, and press down with the fingers upon the other end.

Obs. Observe the effect.

Call the second book the *load* of the lever.

Call the force applied to support the load the *power*.

1. In the above experiment what was the position of the fulcrum with reference to the load and the power ?
2. Use your pencil as a lever with the load between the power and the fulcrum.
3. Use it as a lever with the power between the load and the fulcrum.

b. RELATION OF POWER TO LOAD.

EXPERIMENT 35. (At school.)

Insert a small screw-eye in the middle of a light wooden bar 13 inches long.

Suspend the bar by this screw-eye from the middle of the frame used in Experiment 36.

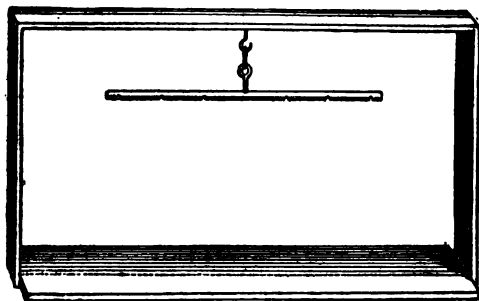


Fig. 26.

If the bar does not balance in a horizontal position, whittle down the heavier arm until it does.

On the under side of this bar cut little notches 2, 4, and 6 inches from the screw-eye towards each end.

Bend one end of a six-inch lead weight into a hook, and hang it as a load upon the bar, so that the middle of the end of the lead will be at a notch 2 inches from the fulcrum.

Obs. 1. Find what power applied at the same distance from the fulcrum will balance this load.

Obs. 2. Find what power applied twice as far from the fulcrum will balance the load.

1. Compare it with the load.

Obs. 3. Find what power applied three times as far from the fulcrum will balance the load.

2. Compare it with the load.

Inf. How does the power required to balance the load vary as the distance of the power from the fulcrum increases?

Obs. 4. Find what power in each of the above positions will raise the load.

Obs. 5. How do the distances moved by the power and load in each of the above positions compare?

When the power required to balance a load is half as great as the load, the distance which it passes in moving the load is as great as that passed by the load.

EXPERIMENT 66. (At school.)

Obs. 1. Find what load placed 2 inches from the fulcrum a power of 2 units applied 2 inches from the fulcrum will balance.

Obs. 2. Applied 4 inches from the fulcrum, it will balance what load 2 inches from the fulcrum?

Obs. 3. Applied 6 inches from the fulcrum, it will balance what load 2 inches from the fulcrum?

EXPERIMENT 67. (At school.)

Obs. Place the load twice as far from the fulcrum as in the last experiment, and see how the power required at any point to balance it is affected.

c. APPLICATIONS.

CROW-BAR.

Describe the crow-bar and its use.

STEELYARD.

Show where the fulcrum is in the steelyard.

Where the load is applied.

Where the power is applied.

How the weight of the load is shown.

2. WHEEL AND AXLE.

a. CONSTRUCTION.

The wheel and axle consists of two connected cylinders of different diameters turning upon a common axis, as shown in Figure 27.

The larger cylinder is called the *wheel*, and the smaller one the *axle*.

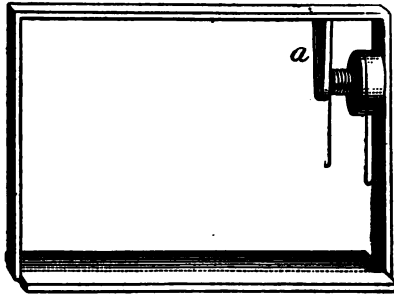


Fig. 27.

The wheel and axle may be made as follows : —

Get a turner to turn for you in one piece two cylinders, each 1 inch long, and one 1 inch and the other 3 inches in diameter, as shown in Figure 28.

At the inner end of the smaller cylinder drive a large gimp tack, allowing the head to project a little.

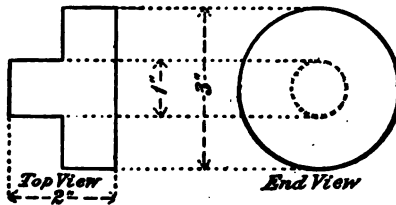


Fig. 28.

In the middle of the opposite side of the larger cylinder drive a small gimp tack.

Make a small hole with an awl in the axis of the cylinders at each end.

Cut out a piece of board 4 inches long, and 3 inches wide at one end and 1 inch at the other. This piece is marked *a* in Figure 27.

Place this piece in position, as shown in the figure, $2\frac{1}{4}$ inches from the end of the frame, and fasten it with screws through the top of the frame.

With an awl make a horizontal hole half an inch above the middle point of the lower end of this piece, and another hole in the same line with this, in the end of the frame.

Place the wheel and axle in position, and fasten it by inserting wire nails through the holes in the frame into the ends of the cylinders.

If it does not turn easily pull out the wire nails and make the holes in the frame a little larger.

b. RELATION OF POWER TO LOAD.

Tie a string 12 inches long to the tack in the wheel, and another to the tack in the axle.

In experimenting, let these strings draw around the wheel and axle in opposite directions.

EXPERIMENT 68. (At school.)

Obs. 1. Hang a load of 6 units upon the string on the axle, and find what power applied to the string on the wheel will balance it.

Obs. 2. Find what power will raise it.

Obs. 3. In moving the load 1 inch the power moves how far?

1. The load is applied how far from the axis?

2. The power is applied how far from the axis?

Inf. 1. The axis of the wheel and axle corresponds to what in the lever?

Inf. 2. The radius of the axle in this experiment corresponds to what in the lever?

Inf. 3. The radius of the wheel corresponds to what in the lever?

In the above experiment the power was applied times as far from the axis as the load, and a

power . . . as great as the load was required to balance it.

Inf. 4. How does the relation of power to load in the wheel and axle compare with the relation of power to load in the lever?

Inf. 5. How far can a load be moved with one application of the lever?

Inf. 6. How far with one application of the wheel and axle?

Inf. 7. What advantage has the wheel and axle over the lever?

Inf. 8. For what uses is the lever better adapted?

EXPERIMENT 69. (At school.)

Place a load of 3 units upon the wheel.

Obs. 1. Find what power applied on the axle will balance it.

Obs. 2. Find what power will move it.

Obs. 3. In raising the load 6 inches how far does the power move?

1. How do these results compare with those obtained with the lever?

c. APPLICATIONS.

What uses of any form of wheel and axle have you seen?

Write a composition upon the *Uses of the Wheel and Axle*, illustrating the various forms by drawings.

3. PULLEYS.

a. DESCRIBE.

Examine one of the pulleys in the frame which we have used, and tell what it consists of.

FIXED PULLEY.

Call a pulley which remains in the same place when in use a *fixed pulley*.

MOVABLE PULLEY.

Call a pulley which changes its place when in use a *movable pulley*.

A good set of pulleys is desirable. If these are not to be had, brass pulleys carefully selected from such as may be found at any hardware store, and at many country stores, will do.

To adapt these for use as movable pulleys wind one end of a piece of $\frac{1}{8}$ -inch wire 8 inches long about the shaft just below the pulley. Bend the wire over the pulley, as shown in Figure 29, wind it down around the shaft, and bend the end into a hook.



Fig. 29

b. RELATION OF POWER TO LOAD.**IN FIXED PULLEYS.****EXPERIMENT 70. (At school.)**

Draw a pliable string over a fixed pulley.

Fasten a load of 6 units to one end of the string.

Obs. 1. Find what power applied at the other end will balance it.

Obs. 2. Find what power will raise it.

Inf. Why is a greater power required to raise a load than to balance it?

EXPERIMENT 71. (At school.)

Pass the cord over three fixed pulleys, as shown in Figure 30.

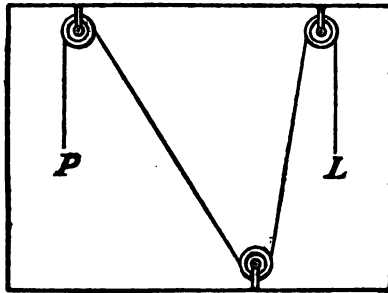


Fig. 30.

Hang a load upon one end of the cord.

Obs. Find what power applied at the other end will balance it.

Inf. Infer what power will balance any load when acting through a cord passing over any number of fixed pulleys.

IN COMBINATIONS OF FIXED AND MOVABLE PULLEYS.

EXPERIMENT 72. (At school.)

Fasten one end of the string to the top of the frame.

Draw the other end under a movable pulley and over a fixed pulley, as indicated in Figure 31.

Fasten to the string a weight which will balance the weight of the movable pulley.

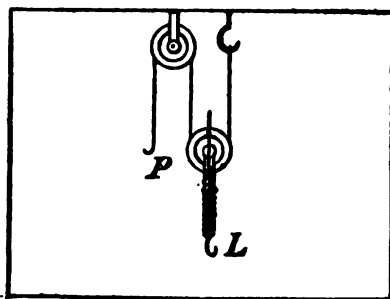


Fig. 31.

Hang a load of 2 pounds on the movable pulley.

Obs. 1. Find what power will balance it.

1. Compare the power and load.

Obs. 2. The movable pulley is supported by how many parts of the cord?

EXPERIMENT 73. (At school.)

Support the movable pulley by three parts of the cord, as shown in Figure 32.

Obs. 1. Balance the weight of the movable pulley, and find how the power which will balance a load, compares with the load.

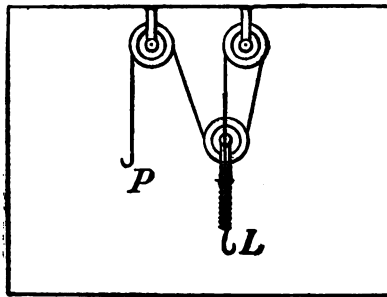


Fig. 32.¹

Obs. 2. In raising the load how do the distances passed by the power and load compare?

c. USE OF PULLEYS.

Inf. 1. Of what use are fixed pulleys?

Inf. 2. What advantage is there in the use of a combination of fixed and movable pulleys?

Write an illustrated account of the ways in which you have seen pulleys applied.

¹ The fixed pulleys *should* be near enough together to make the parts of the cord draw vertically.

4. INCLINED PLANE.

Get a piece of board 6×24 inches.

Fasten a pulley in the middle of one end of it, as shown in Figure 33.

Place the board upon a table with the pulley projecting 3 inches beyond the end of the table.

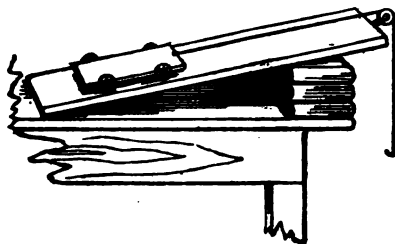


Fig. 33.

Raise the end containing the pulley 4 inches higher than the other end of the board, and support it with books placed under it.

Call the top of this board an *inclined plane*.

a. RELATION OF POWER TO LOAD.

EXPERIMENT 74. (At school.)

Upon this plane place a toy car or carriage with a string fastened to it and passing over the pulley.

Obs. 1. Let go the string, and observe the effect.

Balance the car by a weight upon the string.

Place upon the car a can or box of pebbles weighing 3 pounds.

Obs. 2. Find what power applied at the end of the string will balance this load.

1. How does it compare with the load?
2. How does the height of the plane compare with the length of the plane?

Inf. Infer why the power required is less than the load.

EXPERIMENT 75. (At school.)

Raise the end of the inclined plane 4 inches higher; and repeat the experiment, comparing the power with the load and the height of the plane with its length.

b. USE.

1. Where have you seen inclined planes used for raising loads?

Inf. Of what advantage are they?

5. SCREW.

It is well for the school to own a small jack-screw or bench-screw. If that is not practicable, one may be borrowed of some mechanic or building mover.

1. Turn the screw partly out of the nut, and examine it. What is its general shape?
2. What is there upon the outside of this cylinder? Call this spiral projection the *thread* of the screw.
3. Notice the upper and lower surfaces of the thread as they wind around the cylinder.

Are they level, or inclined?

What do they form?

4. Remove the screw and examine the inside of the nut.

What do you find for the thread of the screw to fit into?

Figure 34 represents a jack-screw as it would appear if the front half of the upper part of the nut could be removed, showing a vertical section of the nut and the front of the screw.

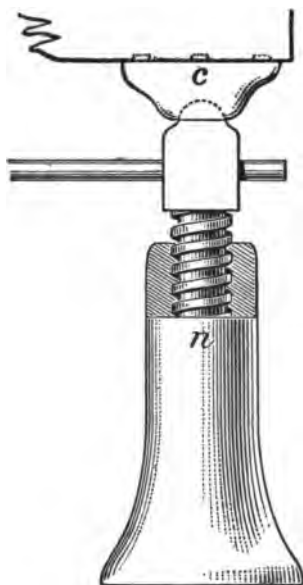


Fig. 34.

5. What does the screw rest upon?
6. What does the under side of the thread slide over when the screw is turned?

See if you can raise a load with a jack-screw.

Explain fully by diagram how it is done.

6. WEDGE.

Examine a wedge.

1. Compare it with the inclined plane.
2. For what have you seen it used?
3. In its use is the load moved over the wedge?
4. What is moved?
5. How is it moved?

APPLICATIONS OF THE SIMPLE MACHINES.

1. Which of these machines have you seen used in raising loads to the upper stories of buildings?
2. A door key belongs to which of these classes of machines?
3. Which machines have you seen used for raising and lowering the wicks of lamps?
4. Which would you use for splitting wood?
5. Which is used in moving a building along the street?
6. What other simple machine is used in working a jack-screw?
7. What machine would you use in loading a barrel of oil upon a truck?
8. What machines have been used for raising "the old oaken bucket" from the well?
9. In which of the simple machines is the resistance of friction least?
10. Can any machine furnish energy?

Write an explanation of the *advantages in the use of simple machines*, giving examples and illustrating by diagrams. Show that:

1. They enable us to do slowly *heavier* work than we could do without them, or to do light work *more rapidly* than we could without them.
2. They enable us to use a force at a more convenient point and in a more convenient direction than we could otherwise use it.
3. They enable us to employ other forces than our own in doing work.

VIII. HEAT.

1. SOURCES OF HEAT.

EXPERIMENT 76. (At home.)

Obs. Hold the back of your hand in the sunshine for a minute, and then in the shade, and notice the difference.

Inf. What is one source of heat?

EXPERIMENT 77. (At home.)

Repeat Experiment 21.

Inf. What is another source of heat?

EXPERIMENT 78. (At home.)

Touch a nail to your cheek.

Hammer one end of it upon an anvil for a few seconds, and touch it to the cheek again.

Obs. Observe the change.

Inf. 1. Infer a third source of heat.

In our study of *Correlation of Forces* we noticed two other sources of heat.

1. What are they?

2. Name the sources of heat which we have considered.

Inf. 2. From which of these sources do we get most heat?

Inf. 3. From which do we get the next greatest supply?

2. EFFECTS OF HEAT.

a. EXPANSION.

(1) OF SOLIDS.

EXPERIMENT 79. (At home.)

Bend one end of a wire 10 inches long into a ring just large enough so that a marble will not drop through it.



Fig. 35.

Obs. 1. Heat the ring hot, and see if the marble will drop through.

Inf. 1. Infer the cause.

Inf. 2. What is one effect of heat?

Derive the term *expansion*.

Obs. 2. Cool the ring, and see if the marble will drop through.

Inf. 3. Infer the cause of this.

1. Give other instances in which you have noticed that heat expands solids.
2. In laying the rails of a railroad what allowance is made on account of this fact?
3. Do you know of any uses made of this fact in the arts?

(2) OF LIQUIDS.

EXPERIMENT 80.

Fill a large test tube with cold water.

Insert a stopper into which has been fitted a small

glass tube, so that the water will rise in the tube above the stopper.

Heat the test tube gently.

Obs. 1. Observe the effect on the water.



Fig. 36.

Inf. 1. What causes this?

Obs. 2. Cool the test tube, and observe.

Inf. 2. Infer the cause of this change.

EXPERIMENT 31. (At home.)

Warm a thermometer bulb.

Obs. 1. Observe the mercury in the tube.

Inf. 1. Infer the cause of the change.

Obs. Inf. 2. Cool the bulb, observe, and infer.

1. Describe the thermometer, telling what parts it consists of, describing each, and telling how it works.
2. Give other instances in which you have noticed that heat expands liquids.

(3) OF GASES.

EXPERIMENT 82. (At school.)

Fill the apparatus used in Experiment 80 with air, insert the glass tube beneath the surface of water, and warm the test tube.

Obs. What is the effect ?

Inf. What causes this action ?

1. What effect of heat is shown in Experiments 79, 80, 81, and 82 ?

A. CHANGES IN STATES OF MATTER.

Liquefaction.

EXPERIMENT 83. (At home.)

Heat a little ice in a tin can or cup.

Obs. State the effect, and give a name to the change.

Derive the name.

Inf. What would be the effect if this heat were given out from the water ?

The change of a liquid to a solid is called *solidification*.

Derive *solidification*.

EXPERIMENT 84. (At school.)

Heat a little lead in an iron spoon.

Obs. 1. Observe the change.

Obs. 2. Allow the lead to cool, and observe the change.

1. Give other instances in which heat changes the state of matter.

EFFECT OF MELTING ON ADJACENT BODIES.

EXPERIMENT 85. (At home.)

In a tin can mix ice, broken into small pieces, with about half its weight of salt.

Obs. 1. Watch the change for a few minutes.

Obs. 2. Then insert your finger in the mixture, and note the temperature.

Into a small test tube pour a few drops of water.

Insert it in the mixture, and leave it for a few minutes.

Obs. 3. Observe the effect on the water in the test tube.

Inf. 1. Infer the cause of this change.

Inf. 2. Infer the effect of melting upon adjacent bodies.

1. What use is made of this fact?

Inf. 3. What effect does the melting of ice and snow have upon the temperature of the air?

Vaporization.

BOILING.

EXPERIMENT 86. (At school.)

Half fill a test tube with water, and heat it carefully by holding it obliquely in the flame for 5 minutes.

ELEMENTARY LESSONS IN PHYSICS.

(3) OF GASES.

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Derive *solidification*.

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Heat a little lead in an iron spoon.

Obs. 1. Observe the change.

Obs. 2. Allow the lead to cool, and observe the change.

1. Give other instances in which state of matter.

EFFECT OF MELTING ON TEMPERATURE

In a tin can mix ice, broken into about half its weight of salt.

Obs. 1. Watch the change for some time.

Obs. 2. Then insert your finger and note the temperature.

Into a small test tube pour a few minutes. Insert it in the mixture, and

Obs. 3. Observe the effect on the tube.

Inf. 1. Infer the cause of this effect.

Inf. 2. Infer the effect of melting on bodies.

1. What use is made of this fact?

Inf. 3. What effect does the melting of snow have upon the temperature of the

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Insert it in the mixture, and leave it for a few minutes.

Obs. 3. Observe the effect on the water in the test tube.

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Insert it in the mixture, and leave it for a few minutes.

Obs. 3. Observe the effect on the water in the test tube.

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Derive *solidification*.

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Obs. 1. Observe the change.

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Vaporization.

BOILING.

EXPERIMENT 86. (At school.)

Half fill a test tube with water, and heat it carefully by holding it obliquely in the flame for 5 minutes.

Obs. 1. Observe what rises from the tube, and the quantity of water left in the tube.

Inf. Infer what change in the state of matter was produced.

Call this change *vaporization*.

Derive the term.

Obs. 2. Describe carefully the process as it occurs in this experiment.

What is formed within the liquid? Rapidly? Or slowly?

Call this process

NOTE. — Some pupils may try additional experiments to determine the boiling points of different liquids, and what the boiling point of any liquid depends upon.

EVAPORATION.

EXPERIMENT 87. (At home.)

Place a *little* water in a shallow tin plate, and heat it gently, without boiling, for half an hour.

Obs. Observe what forms, and the quantity of water remaining.

Inf. Infer what change is taking place.

1. How does the process differ from boiling?

Call it *evaporation*.

Derive the name.

NOTE. — Some pupils may investigate the influences which affect evaporation.

EFFECT OF VAPORIZATION ON ADJACENT BODIES.

EXPERIMENT 88. (At school.)

Place a drop of water on a piece of shaving.

On the drop rest a thin watch crystal with a few drops of ether in it.

With the mouth about 8 inches from the ether, blow steadily across its surface until it has all evaporated.

Obs. Observe the effect upon the water under the crystal.

Inf. 1. Infer the cause of this change.

1. How does sprinkling the floor or the street affect the temperature of the air?
2. How does a summer shower affect the temperature?

Inf. 2. Why?

Explain the manufacture of artificial ice.

CONDENSATION,

EXPERIMENT 89. (At home.)

Obs. Vaporize some water, hold a piece of cold glass in the escaping vapor, and observe the effect.

Inf. Infer the cause of this.

1. What new change in the state of matter occurs in this experiment?

Name the change *condensation*.

Derive the name.

DEW, DEW POINT, FROST, CLOUDS, RAIN, HAIL, SNOW.

EXPERIMENT 90. (At school.)

Half fill a tin fruit can with water at a temperature of about 60 degrees.

Place a chemical thermometer in the water, and add small bits of ice gradually until moisture begins to collect on the outside of the can.

Call this moisture *dew*.

Call the temperature at which it begins to form the *dew point*.

Inf. 1. Infer the cause of the deposit.

Inf. 2. Account for the dew on the grass.

Inf. 3. Account for *frost*.

Inf. 4. If cold air meets warm air, what is the effect upon the warm air?

Inf. 5. Upon the moisture in the air?

Inf. 6. Infer how *rain* is formed; *hail*; *snow*.

3. TRANSFER OF HEAT.

a. RADIATION.

EXPERIMENT 91. (At home.)

Hold your hand for a few seconds near a hot stove or any heated body:

Obs. Observe the effect upon it.

Inf. Infer the cause of this.

EXPERIMENT 92. (At home.)

Obs. Hold the hand in various directions from the heated body, and observe the effect.

Inf. Infer in what directions heat passes from heated bodies.

EXPERIMENT 93. (At home.)

Obs. Placing the hand in the same positions as before, hold a sheet of paper between it and the heated body, and observe the result.

Inf. 1. Infer in what kind of lines heat passes from heated bodies.

Inf. 2. Call this passage of heat from a heated body *radiation*.

Derive the term.

Call the body from which it passes a *radiator*.

Derive *radiator*.

Describe the use of *fire screens*.

NOTE. — Some pupils may investigate the radiating powers of rough and smooth surfaces.

b. CONDUCTION.

EXPERIMENT 94. (At school.)

To a small iron rod about 16 inches long stick 4 or 5 marbles along one side with wax, placing one 3 inches from the end, and the others at intervals of 2 or 3 inches.

Hold the end of the rod in the flame as long as any of the marbles stick.

Obs. State the result.

Inf. 1. Infer the cause.

Call this passage of heat through a body *conduction*.

Derive the name.

GOOD AND POOR CONDUCTORS.

EXPERIMENT 95. (At school.)

Repeat the last experiment, using a slate pencil in place of the iron rod.

Compare the rate at which the heat passes through the pencil with that at which it passed through the iron rod.

Call the pencil a *poor conductor*, and the rod a *good conductor*.

Derive *conductor*.

USES OF POOR CONDUCTORS.

EXPERIMENT 96. (At home.)

Keep a block of oak wood, of pine wood, and of iron, a roll of cotton cloth, of woollen cloth, and of silk cloth, and a thermometer, near together for a few hours in a room where the temperature does not change much.

Obs. 1. Then test the temperature of these bodies with the thermometer, keeping it on each for a few minutes.

Obs. 2. Touch them successively to the cheek, and see if they all feel equally warm.

Inf. 1. Infer the cause of the differences.

Inf. 2. Why is clothing necessary?

Inf. 3. What is the best material for clothing?

1. Mention other uses of poor conductors.

WATER AS A CONDUCTOR.

EXPERIMENT 97. (At school.)

Take a test tube nearly full of water, and, holding it by the lower part, heat it just below the surface of the water until the water begins to boil.

Obs. Observe the temperature of the lower part of the tube.

Inf. Infer what kind of a conductor water is.

Air also is a poor conductor.

What use is made of this fact in constructing houses and refrigerators?

WEIGHT OF HOT AND COLD WATER.

EXPERIMENT 98.

Fill a small can with cold water, and balance it on a scale pan.

Pour out the cold water and fill with hot.

Obs. Place the can on the scale pan, and compare its weight with that of the can of cold water.

Inf. Infer the cause of this difference.

c. CONVECTION.

EXPERIMENT 99. (At home.)

Take a cake pan two thirds full of water, and mix a little fine sawdust with it.

Heat it gently in one place by a flame below.

Obs. Observe the effect in the water.

Inf. 1. How can you explain this movement?

Call this mode of distributing heat *convection*.

Derive *convection*.

Inf. 2. Explain how ocean currents are produced.

EXPERIMENT 100. (At school.)

Fit a broken test tube about 4 inches long with a stopper.

Into this fit a piece of glass tubing (*b c* in Figure 37), 4 inches long.

Bend another piece of tubing, 15 inches long, as shown in Figure 37, *a b*, and fit it into the stopper so that it will reach one inch above the other tube.

Connect these tubes at *b* by a piece of rubber tubing.

1. Explain by diagram the *heating of buildings by hot water*.

Some pupil may construct simple hot-water heating apparatus of glass tubing.

2. Explain by diagram the *furnishing of hot water in a house* from a boiler connected with kitchen range.

Some pupils may construct simple apparatus illustrating this subject.

DRAUGHTS.

EXPERIMENT 101. (At home.)

Hold a lamp chimney over a lamp or gas flame with the left hand, and with the right hand hold a strip of very thin paper one quarter of an inch below the level of the bottom of the chimney, and move it under the chimney on the same level.

Obs. 1. Is the paper affected?



Fig. 38.

Obs. 1. Observe the quantity of water in the flask and in the can, and the temperature of the water in the can.

Do you think the water in the flask has been growing hotter?

Obs. 2. Open the flask, and test it.

Inf. 1. What became of the heat applied?

Inf. 2. What became of the vapor formed?

Inf. 3. What became of the latent heat when this vapor was condensed?

Inf. 4. Explain by diagram the process of *heating by steam*.

Some pupils may construct apparatus illustrating this subject.

EXPERIMENT 106. (At school.)

In one test tube place some fine ice or snow, and in another an equal weight of water.

Obs. 1. Notice the temperature of each.

Obs. 2. Insert both in a can of hot water until the ice is nearly melted, and observe the temperature of each.

Inf. 1. Infer the cause of the difference.

Inf. 2. If no heat were absorbed as latent heat in melting, how long would it take the deepest snow or the thickest ice to melt?

Make a topical outline of these lessons on **heat**.

Write upon some of the topics.

IX. MAGNETISM.**1. MAGNETS.**

Repeat Experiment 18.

Call a body which has this force in it a *magnet*.

Derive the terms *magnet* and *magnetism*.

a. FORMS OF MAGNETS.

Three forms of magnets are in common use.

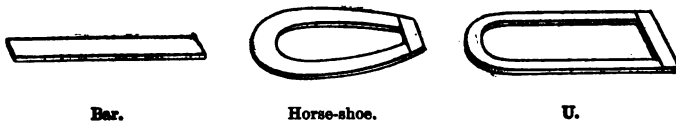


Fig. 40.

b. KINDS OF MAGNETS.**TEMPORARY.****EXPERIMENT 107. (At school.)**

Bring a magnet in contact with a nail, and this nail in contact with another nail.

Obs. 1. Observe the effect.

Inf. 1. What has the first nail become ?

Obs. 2. Separate the first nail from the magnet, and observe the effect.

Inf. 2. What kind of a magnet would you call the nail ?

1. How was it produced ?

Derive the name.

PERMANENT.

EXPERIMENT 108. (At school.)

Rub one end of a magnet along a steel wire or watch spring, always in the same direction.

Obs. 1. Then touch the wire to some iron filings and observe the effect.

Inf. 1. What has it become ?

Obs. 2. Touch it to some iron a few minutes later.

Inf. 2. What kind of a magnet is it ?

1. Do you *observe* the answer to this question, or *infer* it ?

2. How was this magnet produced ?

Derive the name.

c. POLES OF A MAGNET.

EXPERIMENT 109. (At school.)

Scatter iron filings over one side of a magnet.

Raise it and turn it over, or hold it upright.

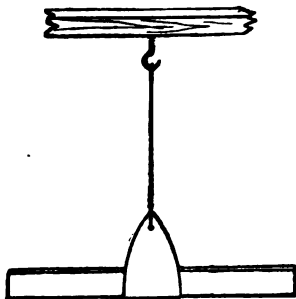


Fig. 41.

Obs. Observe where the iron clings to the magnet.

Inf. Where is the magnetism chiefly manifest?

Call these parts the *poles*.

EXPERIMENT 110. (At school.)

Balance a bar magnet in a paper stirrup and suspend it by a silk thread.

Obs. When it has come to rest observe its direction.

Call the north end of the magnet the *north*, or *positive* (+) pole, and the south end the *south*, or *negative* (−) pole.

d. LAW OF MAGNETS.

EXPERIMENT 111. (At school.)

Bring each pole of another magnet successively near each pole of the suspended magnet, and observe the effect in each case.

Inf. Infer how like poles affect each other and how unlike poles affect each other.

2. TERRESTRIAL MAGNETISM.

a. MAGNETIC NEEDLE.

EXPERIMENT 112. (At school.)

Balance a wire magnet in a loop of silk thread.

Call it a *magnetic needle*.

Suspend it over the middle of a bar magnet.

Obs 1. Observe the direction of the wire magnet.

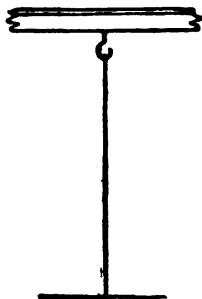


Fig. 42.

Obs. 2. Change the direction of the needle, and observe.

Inf. What controls its direction?

EXPERIMENT 113. (At school.)

Remove the bar magnet, and observe the direction of the needle when it comes to rest.

Inf. What influences the needle's direction now?

Call this influence of the earth upon magnets *terrestrial magnetism*.

Derive *terrestrial*.

b. MAGNETIC DECLINATION.

1. Compare carefully the direction of the magnetic needle with that of a north and south line.

Call the angle formed by a north and south line and the direction of the magnetic needle *magnetic declination*, or the *variation of the needle*.

Derive *declination*.

Describe the mariner's compass and its use.

X. FRICIONAL OR STATIC ELECTRICITY.

1. HOW EXCITED.

For successful work in this subject bright, clear, cold weather and warm, dry apparatus are necessary.

EXPERIMENT 114. (At home.)

Hold a silk ribbon a foot long near the wall of a room.

Obs. 1. See if any peculiar result follows.

Draw the ribbon between two layers of a warm flannel pad with considerable friction, and hold it near the wall.

Obs. 2. Observe the effect.

Inf. Infer the cause of this action. -

EXPERIMENT 115. (At home.)

Warm a sheet of paper, and hold it near the wall of a room.

Obs. 1. See if any peculiar result follows.

Place the paper upon a warm board, and rub it briskly with India rubber.

Obs. 2. Hold it near the wall, and observe the effect.

Inf. Infer the cause.

Repeat Experiment 19.

EXPERIMENT 116. (At school.)

Rub a stick of sealing wax with a flannel pad, and bring the wax near bits of paper.

Obs. Observe the effect.

Inf. 1. Infer the cause.

Call the force which produces these effects *frictional* or *static electricity*.

1. How was it excited ?

2. ELECTROSCOPES.

a. PITH-BALL.

EXPERIMENT 117. (At school.)

Bend a wire 6 inches long into a right angle at its middle point, and insert one end of it in the cork stopper of a bottle as shown in Figure 43.



Fig. 43.

From the outer end of the wire suspend two pith-balls, one quarter of an inch or more in diameter, by a silk thread.

Obs. Bring the excited chimney near the pith-balls, and observe the effect.

Call this apparatus a *pith-ball electroscope*.

Derive *electroscope*.

b. BALANCED BAR.

By heating soften one end of a piece of sealing wax about 2 inches long, and stick it upright upon the centre of a tin box-cover 2 or 3 inches in diameter.

Heat the eye of a needle, and insert it upright in the top of the sealing wax.

With sealing wax, stick a triangular bit of tinfoil on each end of a curved splinter of wood about 6 inches long, and balance it on the point of the needle.

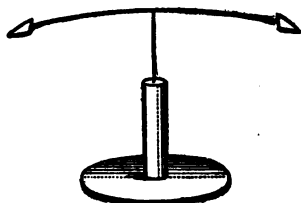


Fig. 44.

Use this balanced bar as an *electroscope*; i. e. to indicate the presence of electricity.

EXPERIMENT 118. (At home.)

Obs. Excite the lamp chimney and bring it near one end of the balanced bar, and observe the effect.

3. KINDS.

EXPERIMENT 119. (At school.)

Obs. 1. Excite the lamp chimney and hold it near the pith-balls for two or three minutes, and observe what happens.

Obs. 2. Try the same with the sealing wax.

EXPERIMENT 120.

Let one pupil excite the lamp chimney and another the sealing wax, and hold them for a minute or two about an inch apart, with the pith-balls between them.

Obs. Observe what happens.

Inf. How can you account for this action of the pith-balls?

EXPERIMENT 121.

Repeat the last two experiments, using the balanced bar instead of the pith-balls.

Call the electricity excited in the lamp chimney *positive* (+), and that excited in the sealing wax *negative* (—).

EXPERIMENT 122.

Find what kind of electricity is excited in the silk pad, and what kind in the flannel pad.

4. LAW.**EXPERIMENT 123.**

Bend a wire 12 inches long into the shape shown in Figure 45, and suspend it by a silk thread.

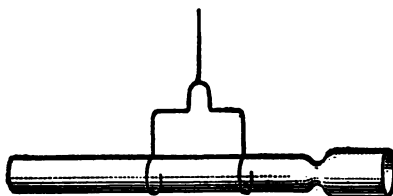


Fig. 45.

Let one pupil excite a lamp chimney and another a second one.

Obs. 1. Lay one of the chimneys upon the wire hooks, bring the other near one end of this, and observe the effect.

Obs. 2. Repeat this experiment, using two sticks of sealing wax in place of the chimneys.

Obs. 3. Repeat, using one chimney and one stick of sealing wax, and observe the effect.

Inf. Infer how bodies charged with the same kind of electricity affect each other, and how those charged with unlike electricities affect each other.

5. CONDUCTION.

CONDUCTORS AND INSULATORS.

EXPERIMENT 124. (At school.)

Lay a piece of glass tubing 1 foot long across the top of a tumbler so that one end of it will come within about one eighth of an inch of one end of the balanced bar.

Obs. 1. Touch the excited chimney to the end of the tube remote from the electroscope, and see if the bar is affected.

Obs. 2. Try the excited sealing wax in place of the chimney.

EXPERIMENT 125. (At school.)

Repeat Experiment 124, using a hard-wood foot rule in place of the glass tube.

EXPERIMENT 126. (At school.)

Repeat, using your lead pencil.

Repeat again, using a key.

Inf. 1. Infer an explanation of the facts observed in Experiments 124 to 126.

Call the action of electricity over a body *conduction*.

Call a body over which electricity acts a *conductor*, and one over which it does not act an *insulator*.

Derive these terms.

Name the conductors and insulators which you have found in these experiments.

Inf. 2. Infer why glass bottles are used in the electroscopes.

Inf. 3. Infer why the pith-balls fly off after contact with an electrified body, and why they repel each other.

Inf. 4. Infer the use of lightning rods.

6. INDUCTION.¹**EXPERIMENT 127. (At home.)**

Support a cylindrical tin box, or can, with the cover on, horizontally upon a dry tumbler, so that one end of the can will be within a quarter of an inch of the bar electroscope.

Bring the excited chimney or sealing wax near the other end of the can, without contact.

Obs. Observe the effect upon the electroscope.

¹ It may be best to omit this topic with classes in grammar schools.

Inf. Infer how this effect can be produced.

Call the development of electricity in a body by the approach of an electrified body, without its coming near enough for a spark to pass, *induction*.

Derive the term.

See what other bodies you can induce electricity in.

See if you can decide what kind of electricity is manifest on the end of the can toward the electroscope. (Recall Experiment 123.)

Obs. and *Inf.* 2. Is there any electricity at the other end?

Obs. and *Inf.* 3. Of what kind is it?

Inf. 4. Infer the first effect of bringing an excited body near an insulated body.

Inf. 5. In view of this, infer why the pith-balls and the bar are attracted to an excited body.

XI. VOLTAIC OR CURRENT ELECTRICITY.**1. VOLTAIC ELEMENT.****EXPERIMENT 128.**

Repeat Experiment 20.

Call this apparatus a *Voltaic element*.

1. What does it consist of?

2. HOW PRODUCED.

Inf. Infer how the electricity was produced in the above experiment.

3. EFFECTS.

The effects and applications of electricity are too numerous and varied to be considered, even in the briefest way, in these Lessons. They form a subject for investigation in the latter part of the High School course.

But we will recall briefly two or three effects which we have already noticed.

a. MAGNETIC.

1. What effect of Voltaic electricity have you already observed?

EXPERIMENT 129. (At school.)

Wind about 30 feet of insulated No. 22 copper wire around a small rod of soft iron 5 or 6 inches long, and connect the ends with the plates of the Voltaic element.

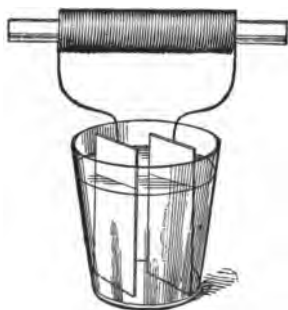


Fig. 46.

Obs. 1. Bring bits of iron near one end of the iron rod, and observe the effect.

Obs. 2. Bring them near the other end, and observe.

Inf. 1. Infer what the rod has become.

Inf. 2. Infer how this change was produced.

Obs. 3. Separate one end of the wire from the plate, and see if the rod retains its magnetism.

Obs. 4. Hold the end of the wire to the plate, and see if the rod is now a magnet.

Obs. 5. Touch a very small tack to the rod, separate the wire from the plate, and see how long the tack is held.

Inf. 3. How long does the rod continue a magnet after the connection between the plates is broken?

Call the iron rod an *electro-magnet*.

Pupils are now prepared to examine and describe the *key* and *receiver* of the telegraph, and the *electric bell* and *press-button*.

The key and press-button are used to make and break connections; and the receiver, or sounder, and the "bell" are applications of electro-magnets.

The construction and working of the telegraph and the electric bell may be described by the pupils in writing.

1. What two effects of Voltaic electricity have you learned?

b. THERMAL.

EXPERIMENT 130. (At school)

Cut the connecting wire of a Grenet battery, and twist around the ends a piece of fine platinum wire so that there will be about one inch of it between the ends of the copper wire.

Obs. Lower the zinc plate, and test the temperature of the platinum wire.

Inf. Infer how the change has been produced.

c. LUMINOUS.

1. How are incandescent electric lights produced?
2. What other luminous effects of electricity have you noticed?

Prepare a topical outline of these lessons in Electricity, and write upon some of the topics.

XII. SOUND.**1. HOW PRODUCED.****EXPERIMENT 131. (At home.)**

Strike one tine of a pitchfork a sharp blow, not too hard.

Obs. Notice what the tine does, and what you hear.

EXPERIMENT 132.

Obs. Pull a piano string a little to one side, let it go, and observe as in the last experiment.

EXPERIMENT 133.

Strike a call bell, and hold a pencil lightly against one edge of the bell.

Obs. Observe the effect as before.



Fig. 47.

Inf. 1. Infer why the pencil moves.

Inf. 2. From these experiments infer what sound is due to.

2. TRANSMISSION OF VIBRATIONS.

a. THROUGH WOOD.

EXPERIMENT 134. (At home.)

Hold a lath horizontal, with one end resting lightly against the panel of a door.

Make a tuning-fork vibrate, and press the end of its handle against the free end of the lath. (A steel table-fork will do.)

Obs. Observe where the sound seems to come from.

Inf. Infer how the vibrations reached the door.

b. THROUGH A STRING.

EXPERIMENT 135. (At home.)

Punch a little hole through the centre of the cover and bottom of a cylindrical tin box.

From the outside insert one end of a string 10 or 12 feet long through the hole in the cover, and the other end through the hole in the bottom. Tie knots in the ends to keep them from pulling out. Let one person hold the open end of the box to his ear, and another person hold the cover far enough away to straighten the string, and sounding the tuning-fork (or table-fork), touch the handle to the box cover.

Obs. 1. The one holding the box to the ear report the effect.

Obs. 2. Where did the sound seem to come from?

Inf. Infer how the vibrations reached the box.

c. THROUGH THE AIR.

EXPERIMENT 136. (At home.)

Lay a piece of writing paper over the mouth of a tumbler, leaving an opening half an inch or less in width, and trim off the outside of the paper so that it will not project more than half an inch beyond the edge of the tumbler.

Press the paper down against the tumbler, and sprinkle a little fine sand on it.

Obs. Sing a strong, full tone, and, slowly raising and lowering the pitch, watch the sand upon the paper.

If the sand is not affected, change the size of the opening slightly, and repeat until it is affected.

Inf. 1. Infer how this effect is produced.

Inf. 2. Infer how the vibrations reached the paper.

In the ear is a little membrane, stretched over a bony framework, and forming the "drum" of the ear, with which the air comes in contact.

Inf. 3. Infer how it will be affected when objects near us are made to vibrate.

These vibrations continuing, reach the auditory nerve, and the sound is heard.

1. What have you observed that would indicate at what rate sound is transmitted through air?

Plan an experiment which will show approximately the velocity of sound in air.

3. VIBRATING STRINGS.

a. LOUDNESS OF TONES.

EXPERIMENT 137. (At school.)

Stretch a violin string over a *sonometer*.

Derive *sonometer*.

With the finger press the string a little to one side, and then let it slip.

Obs. 1. Observe the effect.

Press the string farther to one side, and let it slip.

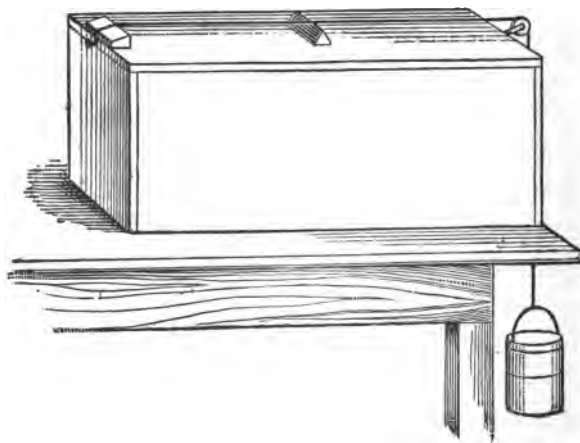


Fig. 48.

Obs. 2. Notice the distance which the string vibrates, and the loudness of the tone.

Obs. 3. Press the string still farther, and observe.

Call the distance through which particles vibrate the *amplitude* of vibration.

Derive *amplitude*.

Inf. Infer what the loudness of a tone depends upon.

Any strong string rubbed with beeswax will do for these experiments.

If a sonometer cannot readily be procured, get a soap-box with a thin, close bottom (Ivory-soap boxes are good), and invert it upon a table.

Insert a screw in the middle of one end, and a pulley in the middle of the other end.

On the top of the box above the screw fasten a block, cut so that the inner edge will be a little higher than the outer edge, as shown in Figure 48.

Make another block in the form of a triangular prism, so that when laid upon one side it will be 1 inch or more in height.

Fasten one end of the string to the screw, and pass the other end over the pulley.

The string may be stretched by the hand or by weights.

b. PITCH OF TONES.

EXPERIMENT 138. (At school.)

Stretch a lighter or a heavier string than was used in the last experiment with the same force (weight), and repeat the experiment.

1. Compare the tone of this string with that of the other.

Inf. Infer whether light strings or heavy ones give higher tones.

EXPERIMENT 139. (At school.)

Obs. Place the movable block at the end next to the pulley, stretch the string with a weight, sound the string, and notice the pitch of its tone.

Move the block inward so as to shorten the vibrating string, and repeat the experiment.

1. Compare the pitch of the tone with that of the tone of the longer string.

2. Shorten the vibrating string more, and repeat the experiment.

Inf. Infer how the tone is affected by the length of the string.

EXPERIMENT 140. (At school.)

Sound a string 16 inches long, and then one 8 inches long and stretched with the same force.

Compare the tones.

EXPERIMENT 141. (At school.)

Stretch a string slightly with the hand.

Obs. 1. Sound it, and observe its pitch.

Obs. 2. Stretch it a little harder, and repeat the experiment.

Obs. 3. Stretch it still harder, and repeat.

Inf. Infer how the tone is affected by increasing the stretching force of the string.

EXPERIMENT 142. (At school.)

Stretch a string 8 or 10 inches long with a force of 1 pound.

Sound the string, and note its pitch.

Stretch the string with a weight of 4 pounds, and repeat.

1. Compare the pitches of these tones.

2. What three things have we learned affect the pitch of tones produced by vibrating strings?
3. What strings give high tones?
4. What strings give low tones?
5. How are the strings of a piano varied to produce the different tones desired?
6. How are pianos tuned?

Repeat experiments 139-142, noticing carefully the *rate of vibration* in each case, and see if you can decide what the pitch of a tone really depends upon.

4. VIBRATING COLUMNS OF AIR.

EXPERIMENT 143. (At school.)

Get or make an organ-pipe with one glass side, *a b*, as shown in Figure 50.

An organ-pipe may be made from a straight lamp chimney, by filing a hole at the lip, *l*, as shown in Figure 49.

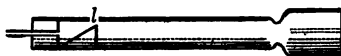


Fig. 49.

But great care is necessary to get it tight and not break the chimney.

Obs. Blow in at the mouthpiece, and observe the effect.

EXPERIMENT 144. (At school.)

Draw a piece of rubber tubing from 16 to 24 inches long over the mouthpiece.

Cut out a piece of writing paper a little smaller

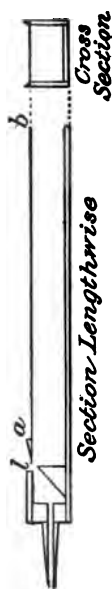


Fig. 50. — ORGAN PIPE.

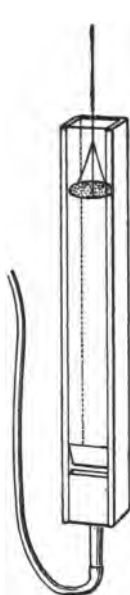


Fig. 51.

than the interior of a cross section of the organ-pipe, and suspend it by a thread.

Scatter a little fine sand upon the paper, and, holding the pipe vertically with the open end upward, so that you can see through the glass side, sound the organ-pipe by blowing through the rubber tube.

Slowly lower the sanded paper into the sounding pipe, and carefully watch the sand.

Obs. What do you observe?

Inf. Infer the cause.

As the air is forced into the organ-pipe, it strikes the lip (*l*, Figure 50), and thus obstructed, it issues from the opening in rapid puffs. The pulsations, thus produced, are transmitted to the column of air within the pipe, and cause it to vibrate.

EXPERIMENT 145. (At home.)

Blow across the mouth of a small bottle so as to produce a tone, and notice its pitch.

EXPERIMENT 146. (At home.)

Blow across the mouth of a larger bottle, and compare the pitch of its tone with that of the tone of the smaller bottle.

EXPERIMENT 147. (At home.)

Obs. 1. Pour a little water into the larger bottle, "sound" it, and compare its tone with that of the "empty" bottle.

Obs. 2. Add more water, and observe how the tone changes.

Inf. Infer how the tone of an organ-pipe is affected by the length of the pipe.

EXPERIMENT 148. (At school.)

Obs. Close the outer end of the organ-pipe airtight, sound it, and compare its tone with that of the open pipe.

Inf. Infer what kind of organ-pipes produce high tones, and what kind produce low tones.

Write a composition upon the *pitch of tones*, deducing the facts from experiments.

Make a topical outline of the lessons on sound.

XIII. LIGHT.**1. SOURCES.**

Name some bodies which originate light.

Call such bodies *luminous bodies*.

Derive *luminous*.

Mention some bodies which do not originate light.

Call such bodies *non-luminous bodies*.

Derive *non-luminous*.

Call a body which receives light from other bodies and reflects it an *illuminated body*.

Derive the term.

1. All light comes originally from what kind of bodies?
2. Name the natural sources of light.
3. Name the chief artificial sources of light.

The profitable study of light requires a *porte lumière* and arrangements for darkening the room.

The windows may be darkened by wide curtains of dark cambric, pinned close over the window-frames, or by shutters made by tacking strong opaque paper over wooden frames made to fit the window-frames.

A *porte lumière* may be bought for about \$5.00; or one suitable for these experiments may be made at an expense of about \$0.50.

TO MAKE A PORTE LUMIÈRE.

Get a piece of pine board 9 inches wide, and as long as the width of a window on the south side of the school-room.

On one side of this board mark out a circle 6 inches in diameter, with its centre $\frac{1}{2}$ inch above the central point of the board.

Saw it out with a compass-saw as marked.

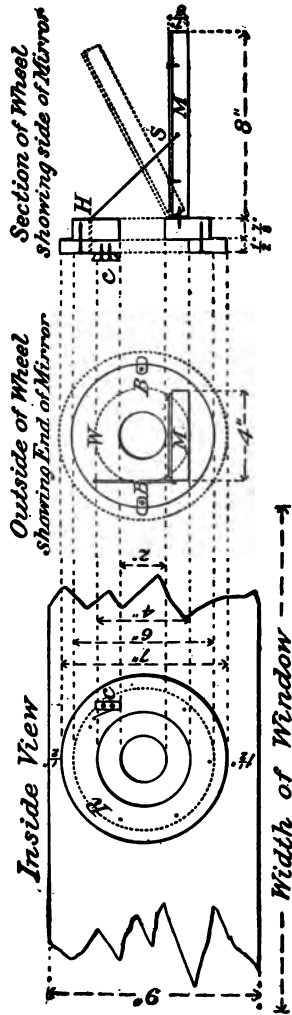


Fig 52. — PORTE LUMIERE.

If necessary, even the edge of this circular piece so that it will turn as a *wheel* in the hole.

In the centre of this wheel bore or cut a round hole 2 inches in diameter.

From $\frac{1}{2}$ inch board cut a ring (*R*, Figure 52) 7 inches in diameter on the outside and 4 inches inside.

With $1\frac{1}{4}$ inch wire nails fasten this ring to one side of the wheel, so that its rim will project beyond the rim of the wheel $\frac{1}{2}$ inch all round.

Cut out a piece of pine board 4×8 inches (*M*, Figure 52).

To one side of this fasten a piece of looking-glass, $3\frac{1}{2} \times 7\frac{1}{2}$ inches, by small screws, placed so their heads will lap over the edge of the looking-glass

With a suitable hinge and rather long screws hang this mirror to the wheel in the position shown in Figure 52, so that the mirror may be raised against the wheel.

In one edge of the mirror, $3\frac{1}{4}$ inches from the wheel, insert a small screw (*S*), letting the head project.

Raise the mirror against the wheel, and with a brad awl make a hole (*H*) through the wheel opposite the screw in the edge of the mirror.

To the screw fasten one end of a string about 18 inches long, and pass the other end through the awl hole.

Upon the ring, a little below and at the right of the awl hole, by means of screws fasten a small cleat (*c*) to hitch the string to. Thus the mirror may be held at any angle desired.

Of hard wood make two buttons (*B, B*) about $1\frac{1}{4} \times \frac{5}{8} \times \frac{1}{4}$ inch, and fasten each with a screw to the wheel, as shown in the figure.

Turn these buttons so that they will not project beyond the rim of the wheel, place the wheel in the board, and fasten it by turning the buttons.

Place the *porte lumière* under the lower sash of a window on the sunny side of the room, and adjust it—by turning the wheel and increasing or diminishing the angle of the mirror—so that it will throw the light squarely and horizontally into the room.

For experiments with small lenses a smaller opening for the admission of light may be needed. A hole of the right size may be cut in a piece of cardboard and the cardboard tacked or pinned over the hole in the wheel.

Derive *porte lumière*.

2. TRANSMISSION.

a. MEDIUM,—TRANSPARENT; TRANSLUCENT.

EXPERIMENT 149. (At school.)

With a *porte lumière* throw some sunlight into a darkened room.

Obs. Can you see the light?

Call that through which it passes a *medium*.

Derive the term.

EXPERIMENT 150. (At school.)

Obs. Hold a piece of window-glass in the path of the light, and observe how much of the light passes through the glass.

1. How much of it passes through the air?

Call the glass and the air *transparent media*.

Derive *transparent*.

EXPERIMENT 151. (At school.)

Obs. Place colored glass, also thin paper, in the path of the light, and observe how much light passes through.

Call such bodies as the colored glass and thin paper *translucent media*.

Derive *translucent*.

1. Name other transparent media.

2. Name other translucent media.

3. How much light will pass through a piece of inch board or a book?

Call these *opaque* bodies.

Derive *opaque*.

b. RAY; c. BEAM.**EXPERIMENT 152. (At school.)**

Strike together two erasers containing crayon dust along the path of light.

Obs. 1. Observe in what kind of lines the light passes.

Call a single line of light a *ray*.

Derive the term.

1. Are there many or few rays of light thrown into the room by the *porte lumière*?

Obs. 2. How do these rays compare in direction?

Call a collection of parallel rays a *beam* of light.

d. PENCIL OF LIGHT.**EXPERIMENT 153. (At school.)**

Place a double convex lens (see page 139) in the beam of light, and render the path of rays beyond the lens visible by crayon dust.

Obs. Observe the relative direction of the rays beyond the lens.

Call a collection of rays converging to the same point or diverging from the same point a *pencil of light*.

The first is called a *converging* pencil.

The second is called a *diverging* pencil.

Derive *pencil*, *converging* and *diverging*.

e. IMAGE BY SMALL APERTURE.-**EXPERIMENT 154. (At school.)**

Bore a hole about half an inch in diameter in one end of a soap-box without cracks, and cover the hole with a piece of tinfoil.

Prick a hole in the tinfoil with a pin.

Invert the box over a lighted candle in a darkened room, and hold a sheet of white paper as a screen before the hole in the tinfoil.

Obs. 1. Observe what forms on the screen.

Inf. 1. See if you can think out and show by diagram how this is formed.

Obs. 2. Bringing the screen near the box, and removing it gradually, observe the effect upon the image.

Inf. 2. See if you can explain the effect by diagram.

EXPERIMENT 155. (At school.)

Through a hole from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in diameter admit light from without into a darkened room, and have a large screen or light wall on the side of the room opposite the hole.

Obs. Observe the result.

f. SHADOW, UMBRA, AND PENUMBRA.**EXPERIMENT 156. (At home.)**

Before a lamp flame in a darkened room hold an opaque body smaller than the flame.

Hold a white screen (paper) just beyond the opaque body, and gradually move it farther away.

Obs. Observe the appearance on the screen.

Inf. See if you can explain the appearance by diagram.

Call the space from which light is shut off by an opaque body a *shadow*.

Call the space from which all the light is shut off the *umbra*.

Call the space from which a part only is shut off the *penumbra*.

Derive these terms.

g. ECLIPSE OF THE MOON.

Is the moon a luminous or an illuminated body?

Where does its light come from?

Is the earth transparent or opaque?

What must there be on the side of the earth away from the sun?

Is the earth larger or smaller than the sun?

What must be the form of the earth's umbra?

What must be the form of the earth's penumbra?

Explain how an eclipse of the moon is produced.

h. ECLIPSE OF THE SUN.

Describe the umbra and penumbra of the moon.

Explain how an eclipse of the sun is produced.

i. VELOCITY OF LIGHT.

It has been found that light passes across the earth's orbit in 16 minutes 36 seconds.

The average distance of the earth from the sun is thought to be about 93,000,000 miles.

How far must the light travel in a second?

j. REFLECTION OF LIGHT.

EXPERIMENT 157. (At school.)

By a *porte lumière* throw a beam of light into a darkened room, and place a mirror in its path.

Render the path of the light visible by crayon dust.

Obs. Observe and state the effect of the mirror upon the light.

Call this turning back rays of light in regular order *reflection*.

Derive the term.

A mirror is what kind of a surface?

What does it do with light?

LAW OF REFLECTION.

Think of a perpendicular to the mirror at the point where the light strikes the mirror.

Call the angle which the rays falling upon the mirror make with this perpendicular the *angle of incidence*.

Derive *incidence*.

Call the angle which the reflected rays make with the perpendicular the *angle of reflection*.

Compare the angle of incidence with the angle of reflection.

DIFFUSED LIGHT.

EXPERIMENT 158. (At school.)

Obs. Place a piece of rough paper in the path of the rays, and see if the light is reflected regularly.

Call light thus scattered by a rough surface *diffused* light.

Derive *diffused*.

IMAGE OF A POINT BY A PLANE MIRROR.

EXPERIMENT 159. (At home.)

Hold the point of your pencil in front of a plane mirror.

Obs. Observe and describe the location of the image of the point, as seen from any position.

Is the image in front of the mirror, or behind it?

How far?

Where with reference to a line perpendicular to the mirror and passing through the point of the pencil?

IMAGE OF AN OBJECT BY A PLANE MIRROR

EXPERIMENT 160. (At home.)

Hold any object before a plane mirror.

Obs. Observe and state the position of the image of each point of the object.

When you look in a mirror, the image of your right eye forms which eye of the image of your face?

IMAGES BY TWO PARALLEL PLANE MIRRORS.

EXPERIMENT 161. (At school.)

Cut out a piece of board in the form of a quadrant with a radius of 10 inches.

Along one of the sides saw two parallel scaths (*a* and *b* in Figure 53) $\frac{1}{4}$ of an inch deep and 4 inches apart; and three other scaths (*c*, *d*, and *e* in the figure), making angles of 30, 60, and 90 degrees respectively with the scath *a*.

In the parallel scaths place two pieces of looking glass, 2 by 6 inches, facing each other.

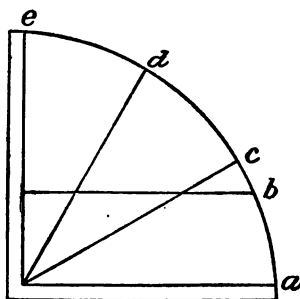


Fig. 53.

Obs. Place a piece of crayon between these mirrors, and see if you can see more than one image of it. How many?

Where are they?

IMAGES BY TWO PLANE MIRRORS AT AN ANGLE.

EXPERIMENT 162. (At school.)

Obs. On the same board arrange the mirrors at angles of 30, 60, and 90 degrees, and find how many images can be seen from one position with the mirrors at each of these angles.

CONCAVE MIRROR, PRINCIPAL FOCUS, FOCAL DISTANCE,
CENTRE OF CURVATURE.

EXPERIMENT 163. (At school.)

Place a concave mirror in the path of a beam of light in a darkened room, so that the light will strike perpendicularly at the centre of the mirror.

Obs. Render the path of the reflected light visible by crayon dust, and describe the direction of the rays.

Draw a diagram showing how the light is reflected.

Call the point through which all the reflected rays pass the *principal focus* of the mirror.

Derive *focus*.

Call its distance from the mirror the *focal distance* of the mirror.

Call the point directly in front of the mirror twice as far away as the principal focus the *centre of curvature* of the mirror.

Inf. Infer why it is so called.

IMAGE BY A CONCAVE MIRROR.

EXPERIMENT 164. (At school.)

In a darkened room place a lighted candle at considerable distance beyond the centre of curvature and a little to the right of it.

Hold a piece of white paper as a screen just to the left of the principal focus, and moving it slowly away from the mirror, see if the image of the candle flame is formed on it.

Obs. Describe the image. (Erect or inverted? Where with reference to the centre of curvature? How large compared with the object?)

EXPERIMENT 165. (At school.)

Bring the candle nearer the centre of curvature, and find and describe the image.

EXPERIMENT 166. (At school.)

Obs. Carry the candle nearer the mirror than the centre of curvature, and find and describe the image.

EXPERIMENT 167. (At school.)

Obs. See if any image is formed when the object is located at the principal focus, within the principal focus, and at the centre of curvature.

Inf. Infer why this is so.

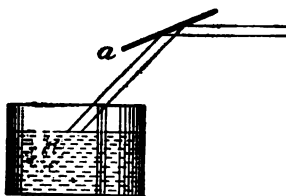


Fig. 54.

2. REFRACTION.

EXPERIMENT 168. (At school.)

By means of a mirror (*a*) throw a beam of light *obliquely* into colored water, and render the path of rays through the air visible by crayon dust.

Hold a long pencil, or straight stick, parallel with the beam above the water, so that the under side of the pencil will just touch the beam along the upper side, and let the lower end of the pencil extend downward to the bottom of the water.

Obs. Do the rays continue parallel with the pencil after entering the water?

Call the change in direction *refraction*.

Derive the term.

EXPERIMENT 169. (At school.)

Obs. Throw the light perpendicularly into the water, and see if there is any refraction.

DIRECTION OF THE CHANGE.

1. Which is the denser medium, air or water?

Think of a perpendicular to the surface of the water at the point where the light enters the water.

2. Is the light bent toward this perpendicular, or away from it, as it enters the water?

3. Under what conditions have you found that light is refracted, and in what direction are the rays bent?

EXPERIMENT 170. (At home.)

Place a cent in a basin just near enough to one side so that you cannot see it with the eye in a certain fixed position.

Without changing the position of the eye, carefully pour in on the farther side of the basin, so

as not to move the cent, enough water to nearly fill the basin.

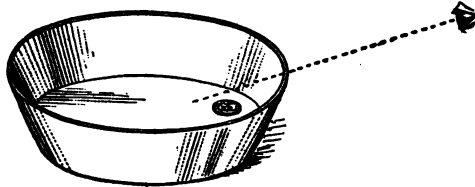


Fig. 55.

Obs. Can you see the cent now?

Inf. Infer in what kind of a line the light must have passed from the cent to the eye.

Compare the direction in which the rays are bent on leaving the water with the direction in which they were bent in Experiment 167 on entering the water.

BY A DOUBLE-CONVEX LENS.

A *double-convex lens* is a circular glass body with its sides curved out so as to make it thickest in the centre.

A section of it is shown in Figure 56.



Fig. 56.

A lens 3 or 4 inches in diameter is desirable for these experiments, though a 2-inch lens might answer.

OF PARALLEL RAYS, PRINCIPAL FOCUS, FOCAL DISTANCE.

EXPERIMENT 171. (At school.)

In a darkened room place a double-convex lens in the path of a beam of light so that the light will strike the lens perpendicularly at its centre.

Render the path of the light visible.

Obs. Observe and state how it passes after leaving the lens.

Call the point through which all the refracted light passes the principal focus of the lens.

Inf. What would you call its distance from the lens?

IMAGE OF AN OBJECT.

EXPERIMENT 172. (At school.)

In a darkened room place the flame of a candle just beyond the principal focus of a double-convex lens.

Obs. Find the image on white paper on the other side of the lens.

Describe the image. (How far away compared with the object? How large? Erect or inverted?)

EXPERIMENT 173. (At school.)

Increase the distance of the flame from the lens, and tell how the image changes.

How far is the flame from the lens when the image is of the same size as the object?

HUMAN EYE.

Describe the human eye and explain how we see.

SIMPLE MICROSCOPE.

Look through a double-convex lens at an object located within the principal focus.

Describe the image seen.

Call this lens a *simple microscope*.

Sometimes two or three lenses placed near together are used as a simple microscope.

Derive the term *microscope*.

COMPOUND MICROSCOPE.

EXPERIMENT 174. (At school.)

In a darkened room place a candle flame just beyond the principal focus of a small double-convex lens.

Find the image of the flame.

Place a larger lens just beyond the image made by this lens.

Look through the larger lens toward the flame.

Describe the image seen.

EXPERIMENT 175. (At school.)

In a light room substitute any small object for the candle flame, and observe and describe.

Call this combination of lenses a *compound microscope*.

REFRACTING TELESCOPE.

EXPERIMENT 176. (At school.)

In a darkened room place a candle flame at considerable distance from a large double-convex lens.

Just beyond the image formed by this lens, place a small lens.

Look through the small lens toward the flame, and describe the image seen.

EXPERIMENT 177. (At school.)

In a light room substitute any object for the candle flame, and observe and describe as before.

Call this combination of lenses a *refracting telescope*.

Derive *telescope*.

Tell how the refracting telescope differs from the compound microscope.

REFRACTION BY A PRISM. SOLAR SPECTRUM.

EXPERIMENT 178. (At school.)

Through a small hole admit light from the sun into a dark room, and have a screen or white wall in the path of the light. (Use a *porte lumière*.)

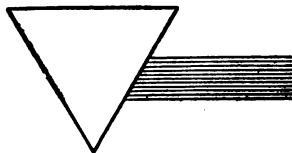


Fig. 57.

What is formed on the screen ?
(See Experiment 154.)

EXPERIMENT 179. (At school.)

Hold a glass prism, base upward, in the path of the beam of light.

Observe the change in the position, form, and color of the image.

Infer the causes of these changes.

Call *this* image of the sun the *solar spectrum*.

Derive the term.

Name the colors of the spectrum, beginning at the top.

Inf. 1. Which rays are refracted most ?

Inf. 2. Which rays are refracted least ?

Write a topical outline of the lessons on light, and a connected composition upon *mirrors* or *refraction*.

PRACTICAL QUESTIONS.

1. When do objects extending upward from the earth cast their longest shadows in the sunlight upon the ground ? Why ?

2. When do they cast their shortest shadows ?

3. Upon what part of the earth are the shadows always long ?

4. When and where do such objects cast no shadows ?

5. What part of the moon shines ?

6. Does it shine upon the earth when it is directly between the sun and the earth ?

7. How much of it shines upon the earth at any time?

8. Do the stars shine by their own light, or by the sun's light?

9. Distinguish between a planet and a fixed star.

10. Which planets do you know?

11. Does the earth shine? With its own light?

12. How can the sun be seen before it has risen above the horizon, or after it has sunk below the horizon?

13. When you look obliquely into clear water, why does it appear shallower than it is?

14. In which of the preceding experiments did light from the object actually pass through the points where the image appeared?

Call an image so formed a *real* image.

15. In which experiments did *no* light from the object pass through the points where the image appeared?

Call such an image a *virtual* image.

XIV. CHEMISTRY OF AIR AND WATER.**THE COMPOSITION OF THE AIR.****EXPERIMENT 180. (At school.)**

Into a shallow pan pour enough water to make it about 1 inch deep.

Float a bit of red phosphorus as large as a good-sized pea upon a piece of cork in the water.

CAUTION. — Phosphorus must be handled with tongs or forceps, and not touched with the fingers. It should be cut under water, and when not in use should be kept under water.

Carefully light the phosphorus with a match; and, holding an inverted quart jar evenly, lower it slowly over the phosphorus until it rests upon the bottom of the pan, and let it remain there.

Obs. 1. Observe carefully all that takes place under the jar.

Describe the substance formed as the phosphorus burns.

See if it remains under the jar.

Inf. 1. Where must it have gone?

Phosphorus is an element, and is often represented by its symbol P.

Inf. 2. Could the cloudy gas have consisted of P alone?

Inf. 3. What could have combined with P?

Inf. 4. Why did the water rise in the jar?

Obs. 2. Was the P all consumed?

Inf. 5. Why did n't the burning continue?

Obs. 3. How does the part of the air left in the jar compare in volume with that which combined with the P?

Call the part of the air which combined with the P
Oxygen.

Derive the terms *oxygen* and *phosphorus*.

Call that which remains in the jar *nitrogen*. It is an element, symbol N.

Derive the term.

Call the substance formed by the union of P and O
phosphorus pentoxide.

Inf. 6. Is it an element or a compound?

Derive the name.

Inf. 7. Infer what proportion of the air is O.

Inf. 8. Infer what proportion of the air is N.

PREPARATION OF OXYGEN.

EXPERIMENT 181. (At school.)

Powder in a mortar a spoonful of thoroughly dried potassium chlorate.

Mix with this an equal quantity of manganese dioxide.

Fill a large hard-glass test tube one third full of this mixture.

Fit a stopper into the mouth of the test tube.

Perforate the stopper and fit into it a glass tube about 16 inches long, bent as shown in the figure.

Cut a hole 1 inch in diameter in the bottom and near the rim of a tin plate (P, Figure 58) 5 or 6 inches in diameter.

Cut another hole $\frac{3}{8}$ of an inch in diameter just below the hem in the rim of the plate and above the hole in the bottom.

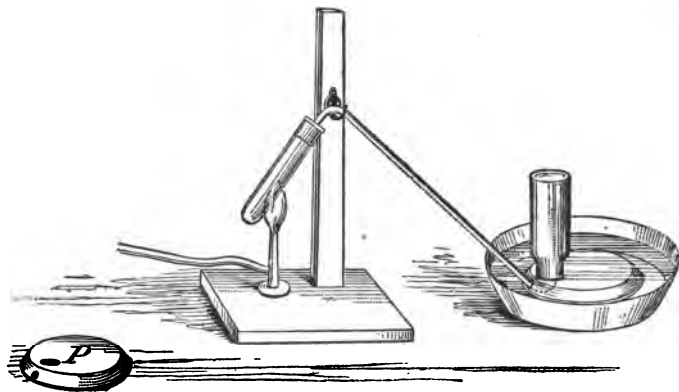


Fig. 58.

Invert this plate in a pan, and pour into the pan enough water to fill it a little above the bottom of the inverted plate.

Fill four horse-radish bottles with water, and, covering the mouths of these with pieces of window glass, invert them, filled with water, upon the bottom of the plate in the pan, placing one of them over the hole in the bottom of the plate, and removing the pieces of window glass.

Support the test tube so that the end of the glass tube will reach beneath the surface of the water in the pan.

Carefully heat the test tube with the gas or alcohol-lamp flame, moving the flame so as to heat the part containing the mixture evenly throughout.

As soon as bubbles begin to escape rapidly from the tube, insert the end of the tube through the hole in the rim of the inverted plate.

When one bottle is filled with gas, promptly close the mouth of it by slipping a piece of window glass under it, remove this bottle, and slip another over the hole in the pan.

In this way fill all the bottles with the gas.

While the bottles are being filled, it may be necessary to dip out a little water, from the pan, to prevent the water from getting too high and floating up the bottles of gas.

Take the delivery tube from the water before removing the flame from the test tube. (Why?)

PROPERTIES OF OXYGEN.

EXPERIMENT 182. (At school.)

Light a splinter of pine wood, and when it gets to burning, blow out the flame and thrust the glowing coal into a jar of oxygen, keeping the jar closed.

Obs. Observe the effect.

EXPERIMENT 183. (At school.)

Wind one end of a piece of wire 10 inches long about a small piece of charcoal, ignite the charcoal, and thrust it into the second jar of oxygen.

Obs. Observe the effect.

The charcoal consists chiefly of the element carbon (C).

EXPERIMENT 184. (At school.)

Wind one end of a piece of wire 10 inches long about a piece of crayon, as shown in Figure 59.

Hollow out the top of the crayon, and, place a piece of roll sulphur (brimstone) as large as a pea in the hollow.



Fig. 59.

Ignite the sulphur and lower it into a jar of oxygen.

Obs. Observe the effect.

EXPERIMENT 185. (At school.)

Heat one end of a piece of fine iron or steel wire, and dip it into powdered sulphur, so as to melt the sulphur and make it stick to the wire.

Ignite the sulphur on the end of the wire, and insert it in a jar of oxygen.

Obs. Observe the effect.

Inf. 1. What do these experiments show about the affinity of oxygen for other elements?

A compound of oxygen with another element is called an *oxide*.

Inf. 2. What different oxides have been formed in these experiments?

Write a connected description of oxygen, — its *preparation* and *properties*.

The rapid union of oxygen with another element accompanied by light and heat is called *combustion*.

Derive the name.

COMBUSTION, COMPOSITION OF WATER.

A candle is composed chiefly of carbon and hydrogen.

EXPERIMENT 186. (At home.)

Light a candle, and hold a cold lamp chimney over it.

Obs. What collects on the chimney?

Inf. 1. What is one substance produced in the burning of the candle?

Inf. 2. What is probably one of the elements of which it is composed? (Recall definition of combustion.)

Let us see if we can learn what the other part of water is.



Fig. 60.

EXPERIMENT 187. (At school.)

Fill a horse-radish bottle with water, and, holding a glass plate over its mouth, invert it, and place it in a pan containing a little water.

Wrap a piece of sodium as large as a pea in a paper, and, holding it with forceps, place it quickly under the jar without raising the mouth of the jar out of the water.

Obs. 1. Observe what happens.

Cover the mouth of the jar, and place it upright upon the table.

Light one end of a splinter of pine wood 1 foot long or more, slip the cover aside, and thrust the burning end of the splinter quickly into the lower part of the bottle.

Obs. 2. Observe what happens to the burning stick, and to the gas in the bottle.

Obs. 3. Notice what forms on the inside of the bottle.

Inf. 1. This water was formed in what process?

Inf. 2. Then it was formed from what substances?

Inf. 3. From what substance do you think the gas came? Why?

1. Describe the gas.

[How does it differ from O? (See *Obs.* 2.)]

It is *hydrogen* (H).

Derive the name. (See *oxygen*.)

Inf. 4. What is water composed of?

Obs. 4. When a lamp or gas is lighted and a cold chimney is placed over the flame, what gathers on the chimney?

Inf. 5. Where do the elements which form it come from?

Let us see if we can learn whether any other substance than water is formed in the burning of the candle.

EXPERIMENT 188. (At school.)

Fit a vaseline bottle, or other wide mouthed bottle, with a good stopper.

Into this stopper fit air-tight two glass tubes, one about 10 inches long, just reaching through the stopper from above, and the other long enough to reach nearly to the bottom of the bottle and project an inch above the top of the stopper.

By means of a piece of rubber tubing 6 or 8 inches long, connect the top of this last tube with the tube of a small tin tunnel

Fill the bottle two thirds full of water.

Obs. 1. Placing the top of the long tube in the mouth, draw in a long breath from the bottle, and observe the effect.

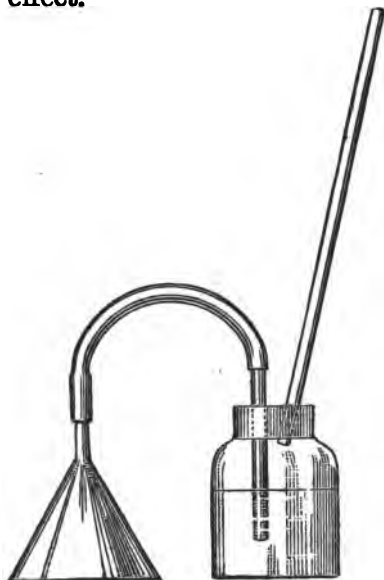


Fig. 61.

Inf. What is the gas that bubbles up through the water? Why does it enter the bottle?

Does the water seem to be affected by it?

Hold the mouth of the tunnel a little above a burning candle, and draw in one or two long breaths as before.

Obs. 2. Is the water affected?

EXPERIMENT 189. (At school.)

Pour out the water from the bottle, and pour in as much lime-water.

Obs. 1. Repeat the two parts of the last experiment just as with water, and notice any effect upon the lime-water.

Obs. 2. Let the bottle stand for a short time, observe any change in the liquid, and notice carefully the bottom of the bottle.

Inf. 1. Infer what the coloring of the liquid was due to.

Inf. 2. Infer how many substances must have combined to form this new substance.

Inf. 3. Infer where they must have come from.

Inf. 4. Could that which came from the burning candle have been the water?

Why not?

Inf. 5. What state of matter was it?

We will prepare some of it in another way.

EXPERIMENT 190. (At school.)

Prepare a horse-radish bottle of O, and, keeping the jar closed as much as possible, repeat Experiment 183.

Inf. 1. Is the substance left in the jar O? How do you know?

Inf. 2. What was it formed from?

Inf. 3. Infer what *element* combined with the oxygen.

The gas formed is called *carbon dioxide*.

EXPERIMENT 191. (At school.)

Obs. Thrust a lighted match into the jar in which the charcoal was burned, and observe the effect.

EXPERIMENT 192. (At school.)

Obs. Lower a lighted candle into the jar, and observe the effect.

In these experiments keep the jar closed as much as possible.

EXPERIMENT 193. (At school.)

Obs. Pour a little lime-water into the jar, shake it, and observe the effect.

Inf. 1. Infer what the substance was which came from the burning candle and acted upon the lime-water.

Inf. 2. What two substances are formed in the burning of a candle?

Supplementary experiments may be taken to see if carbon dioxide is formed in the burning of kerosene, illuminating gas, and wood.

CHANGES IN AIR IN THE HUMAN BODY.**EXPERIMENT 194. (At home.)**

Obs. Breathe upon a cool piece of glass or china, and observe the effect.

Inf. Infer one substance given out in breathing.

EXPERIMENT 195. (At school.)

Obs. Refill with lime-water the bottle used in Experiments 188-9, remove the short glass tube from the stopper, push the other tube through the stopper far enough to reach nearly to the bottom of the bottle, breathe out through the glass tube, and observe the effect upon the lime-water.

Inf. 1. Infer another substance given out in breathing.

1. Compare the substances given out in breathing with those formed in the burning of the candle.

2. What substance is taken out of the air in combustion?

Inf. 2. Infer what is taken from the air in the act of breathing.

Inf. 3. What objections are there to breathing the same air over and over?

Inf. 4. Does a lighted lamp or gas jet improve, or injure the air of a room for breathing?

Three men had occupied the closed cabin of a boat for an hour, when it was found that a match would not burn in the cabin.

Inf. 5. Infer why.

Inf. 6. Was such air fit to breathe?

Inf. 7. What must be done with the air of an occupied room to keep it fit for breathing?

Describe fully in writing, with drawings of apparatus, experiments showing changes in the burning candle and in the human body.

Is your school-house properly ventilated?

If so, write a description of the system, with diagrams.

If not, think out a good plan for ventilating it, and present it in writing, with diagrams.

PREFIXES AND SUFFIXES

OCCURRING IN WORDS TO BE DERIVED IN THIS STUDY.

LATIN PREFIXES.

ad-	} = to.
at-	
con-	{ = with, together.
com-	
co-	
cor-	
de-	= down, off.
dif-	{ = apart.
di-	
ex-	{ = out.
e-	
in-	{ = not, into, on.
im-	
il-	
non-	= not.
pen-	= almost.
re-	= back, again.
sub-	= under, after.
trans-	{ across, beyond, through.

LATIN SUFFIXES.

-able	= that may be.
-al	{ = relating to, like.
-ar	
-ary	
-ant	{ that which (in nouns). same as -ing (in adjs.).
-ent	
-ance	{ = condition, quality.
-ence	
-or	= that which.
-fic	= making.
-ian	= belonging to.
-ion	= act of, quality of, result of
-id	= like, relating to.
-ism	{ = quality.
-ity	
-ive	= having the power of.
-ment	= condition.
-ous	= abounding in.
-ule	{ = minute.
-ulum	

GREEK PREFIXES.

a-	= not, without.
di-	= two.
pent-	= five.

GREEK SUFFIXES.

-ide	= composed of.
-ize	= make, render.

ANGLO-SAXON PREFIX.

un-	= not.
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HINTS FOR MAKING APPARATUS.

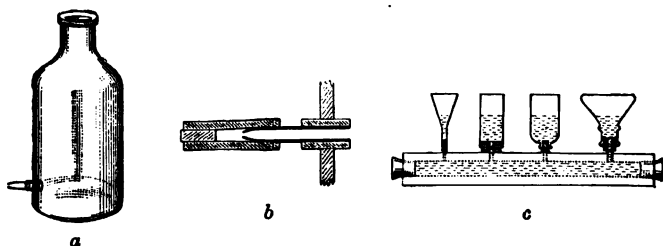
AN almost endless variety of simple apparatus may be made by any one interested in the subject of physics, if he will exercise a little ingenuity and devote a small portion of his time as occasion calls for new things. Work on things of this kind is a relief from ordinary school duties. The very simplest illustrations of great facts make impressions far more valuable than demonstrations with complex and highly finished apparatus furnished by the stores. With bottles, glass tubing, rubber tubing, corks, rubber stoppers, and tin cans one can fit up a very interesting and useful laboratory.

In the first place one needs to practise drilling holes in bottles, lamp chimneys, etc., and cutting off bottles. Any one who uses files will give away worn out files, which are as good as new for this work.

Now let us suppose we are going to drill a hole in the side of a bottle. Break off a little of the end of a three-cornered file, so as to make sharp corners at the end, and scratch a place where the hole is to be drilled; then turn the file back and forth, frequently wetting the end in water, or spirits of turpentine, and by careful, patient work for about five minutes we shall succeed in making a hole. When the hole is nearly through, care must be taken not to have it break through suddenly and crack the glass. Several trials may be necessary at first to learn just how to do it successfully. If the file becomes dulled on the end, chip off small pieces with a hammer.

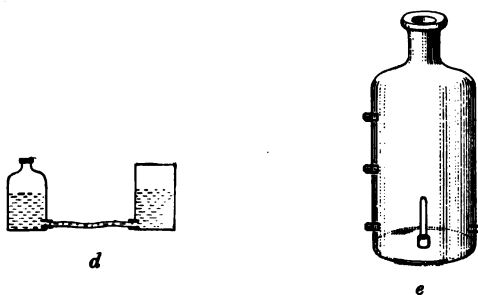
After the hole is drilled, we wish to fit in a tube or spout. Cut off a piece of rubber tubing about half an inch long, wet it,

and insert it into the hole. Then make a spout of glass tubing, and insert it into the piece of rubber already in the hole. This makes an air-tight and water-tight arrangement, shown in figure *a*. A bottle may have several holes for different experiments, and those not in use may be plugged by inserting a glass plug instead of the glass spout. By slipping over the



end of a spout a short piece of rubber tubing plugged at one end, as shown in *b*, it may be closed till the time comes to have the water run.

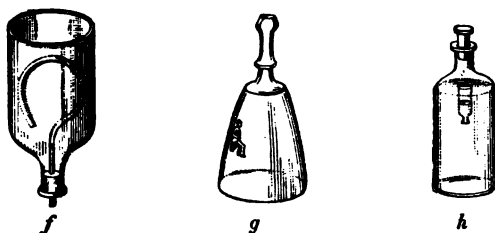
To cut off a bottle, scratch around it with the sharp edge of a file, and follow the scratch with a small jet of gas flame from a glass nozzle, connected with the gas pipe by a rubber tube.



The bottle will then break squarely. Where gas cannot be had, a little filing and applying the sharp edge of a hot iron works fairly, though it is not so sure as the gas flame.

That water seeks its level may be shown by bottles of different shapes and sizes with holes bored in the bottoms, or the bottoms broken off, to let the air out. With perforated corks and glass tubing, connect them with a hole bored lengthwise through a short strip of board and corked at each end, as shown in *c*. A still simpler arrangement is to use only two bottles, or a bottle and a tin can (*d*) connected by rubber tubing.

The pressure of liquids may be shown with a bottle like that represented in *e*. Push it down into a glass jar of water, and see the water spout upward in the bottle. Plug up the hole in



the bottom, and put spouts into the side holes. Notice the difference in the force of the jets. Many other experiments can be performed with a bottle of this kind.

Break off a good-sized bottle, and run a siphon down through the cork, as in figure *f*. This makes a good Tantalus cup.

The diving bell may be illustrated by sticking a small image of a man on the inside of a tumbler or goblet with sealing wax (*g*). The Cartesian diver may be shown by filling a little vial full enough of water so that it will just float; then carefully put it, mouth downward, into a bottle of water (*h*). Pushing the stopper of the bottle down will compress the air enough to sink the vial, and pulling the cork up will cause it to rise again.

The Hero fountain, the hydraulic press, and many pieces of electrical apparatus are easily made, and when once made, form a permanent set of apparatus, which encourages the pupil to original investigation and independent thought and action.

OBSERVATIONS, INFERENCES,
AND
OTHER FACTS CALLED FOR IN THE FORE-
GOING LESSONS.

EXPERIMENT 2.

Obs. The water under the tumbler is nearly on a level with the mouth of the tumbler.

Inf. 1. The air in the tumbler keeps the water from rising higher.

Inf. 2. The air takes up all the room in the tumbler, and there is none left for the water.

BODY.

1. A stone, a skate, and a boy take up room.
2. A thought does not take up room.
3. Joy, sadness, love, hate, and goodness do not take up room.
4. A pen, a stopper, a tumbler, a bat, a sheet of paper, and a slice of steak are pieces of matter.
5. A body is a piece of matter.

SUBSTANCE.

6. Water, ink, glass, wood, steel, and cork are different kinds of matter.

7. A substance is matter of a single kind.

The term *substance* is formed from the Latin *sub*, under, and *stare*, *stans*, standing; *i. e.*, that which stands under (the external qualities).

IMPENETRABILITY.

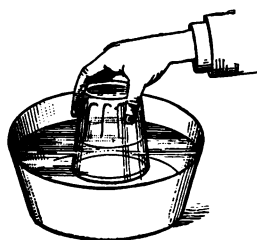
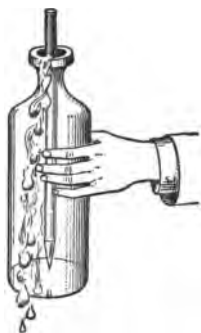
Inf. 3. Only one body can occupy the same space at the same time.

The word *impenetrability* is formed from the Latin *im*, not, *penetrare*, to put in, *able*, capable of, and *ity*, the quality of; *i. e.*, the quality of not being able to be put in.

The following composition is offered as a sample of what may be expected from pupils in this work.

THE IMPENETRABILITY OF MATTER.

If a bottle be filled with water, and a long pencil thrust into it, some of the water will run over. As the bottle was

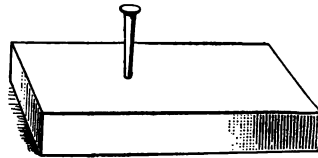


full of water, there was no room for the pencil; and when it was put in, the water was forced out.

If an inverted tumbler held evenly is lowered into water, the water does not rise much inside of the tumbler; for the

room in the tumbler is occupied by the air, and the water cannot get in there unless the air gets out.

When a nail is driven into a block of wood, it forces the fibres of wood aside, crowding them closer together, and makes room for itself.



Whatever, like the pencil, the air, or the water, *occupies room* is *matter*. A thought, a feeling, or a wish requires no space, and is not matter. A *portion of matter*, like the water in the pan, the air in the tumbler, or a rubber eraser, is a *body*.

No two of these bodies could occupy the same space at the same time. This is true of all bodies. Thus matter is said to be impenetrable; and the property of matter by which no two bodies can occupy the same space at the same time is called *impenetrability*.

II. DIVISIONS OF MATTER.

MOLECULE.

Molecule is formed from the Latin *moles*, a huge shapeless quantity of matter, with the diminutive ending *cule*, little; *i. e.*, a little quantity of matter.

MASS.

Mass is formed from the Latin *massa*, that which sticks together like dough, a lump.

1. A pound of butter, an iron weight, a gallon of water, a piece of board, a piece of coal, and a rubber eraser are masses of matter.

COMPOUND.

Obs. Sodium is a soft, silvery-looking metal, easily cut with a knife.

Chlorine is a greenish-yellow gas with a strong suffocating odor.

2. Compounds are substances which have been found to be composed of two or more different kinds of matter combined in definite proportions.

The term *compound* is from the Latin *ponere*, to put, and the prefix *com*, together; something put together.

ELEMENT.

3. "Such substances" are those which have never been separated into different kinds of matter.

Element is from the Latin *elementum*, one of the first principles of things.

4. A molecule of salt contains the elements sodium and chlorine.

Inf. There must be *less* of the sodium than of the salt in a molecule.

ATOM.

5. An *atom* is the smallest particle of matter which can exist combined with other particles. It is always an element.

Atom is formed from the Greek *ἀ*, not, and *τομή*, to be cut; *i. e.*, not to be cut.

6. We have considered *masses*, *molecules*, and *atoms*.

7. I have seen masses of matter.

Inf. 2. The other divisions must exist. There must be a smallest quantity of matter which can exist by itself, and a smallest quantity which can exist combined with other matter.

SIZE OF MOLECULES.

EXPERIMENT 4.

Obs. The water is turned blue.

Inf. 1. The color of the "bluing" is due to little particles of a blue substance floating in the liquid.

Inf. 2. These same particles color the water.

Inf. 3. They are scattered through the water.

Inf. 4. The molecules of this coloring matter must be exceedingly small.

Inf. 5. Molecules must be very small.

III. STATES OF MATTER.

1. LIQUIDS.

EXPERIMENT 5.

Obs. 1. The finger moves very easily through the water.

Inf. 1. The particles of water move easily among themselves.

Obs. 2. A drop of water forms at the end of the finger.

Inf. 2. The particles tend to cling together.

1. The particles of water move freely among themselves, but tend to cling together.

2. The same is true of *alcohol*, *milk*, and *kerosene*.

3. These substances may be called *liquids*.

4. Liquids are substances whose particles move freely among themselves, but tend to cling together.

Liquid is formed from the Latin *liquidus*, from *liquere*, to be fluid, or flow; i. e., a substance which will flow.

2. SOLIDS.

5. The particles of wood, iron, and glass cling together, but do not move freely among themselves.

EXPERIMENT 6.

Obs. The outer end of the sealing wax is slowly bent downward.

Inf. 1. The molecules of wax have been slowly moved among themselves.

Inf. 2. Such substances as wood, iron, and wax are called solids.

The particles of these substances tend to cling together, and do not move freely among themselves.

Solids are substances whose particles tend to cling together, and do not move freely among themselves.

Solid is formed from the Latin *solidus*, firm.

3. AERIFORM MATTER.

EXPERIMENT 7.

Obs. 1. The lower half of one bottle is filled with water; the upper half and the other bottle are filled with air.

Obs. 2. Some of the water goes through the tube into the other bottle.

Inf. 1. Some of the air went from the first bottle into the lungs, leaving less air for the space than there was in the upper half of the other bottle. The more crowded or dense air spread out, and drove some of the water through the tube.

Inf. 2. Molecules of air tend to separate.

1. Its particles tend to separate.

2. Its particles move freely among themselves.

3. Its particles move freely among themselves, and tend to separate.

4. Aeriform matter is matter whose particles move freely among themselves, and tend to separate.

Aeriform is from the Latin *aer*, air, and *forma*, shape, nature, or kind.

5. Chlorine is aeriform matter.

6. Liquids and aeriform matter are called *fluids*.

GAS AND VAPOR

EXPERIMENT 8.

Obs. Aeriform matter is formed and goes into the air.

Inf. 1. It is formed from the water.

Inf. 2. When wet clothing dries, the water goes into the air.

1. We cannot see this water in the air.

2. Water is ordinarily a liquid.

3. This invisible water in the air is aeriform matter.

4. Vapor is aeriform matter of a kind which is more commonly found in the liquid or solid form; while air does not occur in the liquid or solid state.

5. Chlorine, illuminating gas, and "laughing" gas are gases.

IV. CHANGES IN MATTER.

1. CHEMICAL CHANGE.

EXPERIMENT 9.

NOTE. — If the teacher wishes to show all the changes which occur in this experiment, let him fit the test tube with a perforated stopper into which a short piece of glass tubing has been fitted, and insert the stopper, after adding the acid. It will then be seen that the first gas

in the test tube is of a reddish-brown color; but after all the air has escaped from the test tube, the gas which is being formed is colorless, and becomes reddish-brown only when it mingles with air. Hence it must combine with the air, or with something in the air, and form a new gas. The notes which follow correspond with the directions as given in the manual.

Obs. Little bubbles form in the liquid, a reddish-brown gas fills the test tube and escapes, and the liquid becomes blue.

Inf. 1. Neither copper nor nitric acid would turn the liquid blue.

A blue substance must have been formed, which is dissolved in the liquid.

Inf. 2. Two new substances are being formed.

1. Each differs from copper in color, and the gas is a different state of matter.

2. They differ from nitric acid in the same particulars.

Inf. 3. They must have been formed from the copper and nitric acid, and the air.

3. They were formed within the test tube, and there was nothing else there.

Inf. 4. The molecules of the new substances must be different from the molecules of copper and nitric acid; otherwise a collection of molecules — a mass — would not be different.

Inf. 5. The atoms must be the same; they cannot be changed; and no others were present.

Chemical is probably formed from the Greek *χυμός*, juice, with the suffix *al*, relating to. Chemistry seems to have dealt at first with the extraction of juices from plants.

Inf. 6. The copper and nitric acid were not changed into nothing.

Inf. 7. Their atoms combined in new ways to form the substances.

4. (The pupil has probably seen wood, coal, oil, gas, and alcohol burn, metals rust, and other substances decay and ferment.)

2. PHYSICAL CHANGE.

1. No new substances were formed in Experiment 1.
2. In the ninth experiment two new substances were formed.
3. Only physical changes have occurred in the other experiments thus far.

Physics is derived from the Greek φυσικός, from φύσις, nature, from φέειν, to bring forth, to produce. Thus, from its formation, it would mean the knowledge of nature.

The termination *al* would give to physical the meaning *pertaining to nature*.

Call the knowledge of chemical changes *chemistry*.

V. FORCE.

1. DEFINITION.

Force comes from the Latin *fortia*, from *fortis*, strong.

2. PHYSICAL AND CHEMICAL.

Inf. 1. The cause of a physical change is called a *physical force*.

Inf. 2. The cause of a chemical change is called a *chemical force*.

Affinity is formed from the Latin *finis*, boundary, limit, with the prefix *af* (for *ad*), to or near, and the suffix *ity*,

the state of being. Hence it would mean the state of having boundaries together. It is used to mean the force which holds them together.

1. It acts between atoms.
2. Physical forces act between molecules or masses.

3. DIFFERENT FORCES.

a. MUSCULAR FORCE.

EXPERIMENT 10.

Inf. 1. Force produces the change.

1. The force was exerted by *muscles*.

Inf. 2. A force so exerted may be called muscular force.

2. Bending the finger, raising the eyelid, turning the head, and every movement of any organ of an animal is the effect of muscular force.

b. GRAVITATION.

EXPERIMENT 11.

Obs. 1. The blocks begin to move about.

Obs. 2. The chips have come together, mostly around the outside of the pail.

Inf. Some force must have *drawn* them together and to the sides of the pail.

When two boats are near each other, they tend to come in contact. A vessel near a wharf seems to be drawn towards it.

EXPERIMENT 12.

Obs. The brick falls to the ground.

Inf. Some force must draw it downward.

EXPERIMENT 13.

Obs. 1. It presses downward.

Inf. 1. Some force must draw it downward.

1. This force acts between masses of matter.
2. It drew the bodies towards each other.
3. Gravitation is the force which draws masses of matter towards each other.

Gravitation comes from the Latin *gravis*, heavy, with the suffixes *at(e)*, to make, and *ion*, that which; *i. e.*, that which makes heavy.

GRAVITY.

4. In the last two experiments gravitation acted between the earth and the brick.
5. This force acts between the earth, and bodies on or near its surface.

Gravity is derived from the Latin *gravis*, heavy, with the suffix *ity*, the state or quality of being.

6. The name *gravitation* also applies to this force.
7. Gravity is the more definite name, since it applies only to attraction between the earth and other bodies near it.

Inf. 2. A force which draws matter together may be called *attraction*.

Molar is derived from the Latin *moles*, mass, with the suffix *ar*, belonging to; belonging to masses.

Attraction is from the Latin *trahere*, *tractum*, to draw, with the prefix *at* (for *ad*), to or towards, and the suffix *ion*, that which (in this case); that which draws together.

Obs. 2. The string pulls on the fingers.

Obs. 3. The chestnut flies off in a straight line.

Inf. 3. A body moving in the circumference of a circle tends to move in a straight line.

8. Mud flying off from carriage wheels, shot and stones thrown from a sling, show this tendency.
9. It is a tendency of bodies moving in the circumference of a circle to move off in a straight line.

Centrifugal comes from the Latin *centrum*, centre, and *fugere*, to flee; fleeing from the centre.

Inf. 4. Gravitation prevents the planets from moving away from the sun.

c. COHESION.

Inf. 5. It might be called *molecular attraction*.

10. It acts between molecules of the same kind.

Call the force which holds molecules of the same kind together *cohesion*.

Cohesion is derived from the Latin *hærere*, to stick, with the prefix *co* (for *con*), together, and the suffix *ion*, that which; *i. e.*, that which causes to stick together.

d. ADHESION.

EXPERIMENT 14.

Obs. The pencil is wet.

Inf. Some force causes the water to stick to the pencil.

EXPERIMENT 15.

Obs. Some of the lead remains on the paper.

Inf. Some force causes the lead to stick to the paper.

1. The molecules of lead and paper are unlike.

Adhesion is derived from same root as cohesion. *Ad* means to.

2. Adhesion holds molecules of different substances together, and cohesion holds molecules of the same substance together.

3. They both hold molecules together.

e. HEAT.

EXPERIMENT 16.

Obs. The wax melts.

f. LIGHT.

EXPERIMENT 17.

Obs. The half of the paper exposed to the light is turned dark ; the other half remains unchanged.

Inf. The light produces this change.

g. MAGNETISM.

EXPERIMENT 18.

Obs. The pieces of *iron* and *steel* cling to the magnet. Other substances do not seem to be affected.

Inf. Some force in the magnet must have attracted the iron and steel.

Magnet is from *Magnesia*, the name of a city in Asia Minor where the loadstone, or natural magnet, occurs.

The suffix *ism* in *magnetism* means the quality of, or power of.

h. FRICTIONAL ELECTRICITY.

EXPERIMENT 19.

Obs. 1. The chimney and the pad do not affect the paper.

Obs. 2. The bits of paper fly to the chimney and the pad, and after a few seconds fly off again.

Inf. 1. Some force must cause this action.

Inf. 2. This force was produced by the rubbing.

Frictional is from the Latin *fricare*, *frictum*, to rub, *ion*, the act of, and *al*, pertaining to.

Electricity is from the Greek *ἤλεκτρον*, amber, and *ity*, the quality of. It was so named because it was produced by friction of amber.

i. VOLTAIC ELECTRICITY.

EXPERIMENT 20.

Obs. 1. Bubbles of gas escape from the zinc plate.

Obs. 2. They work towards the copper plate.

Inf. 1. A chemical change is taking place.

Obs. 3. The action is the same as when the ends of the plates were in contact.

Obs. 4. The needle was not affected.

Obs. 5. The direction of the needle is changed.

Inf. 2. It was developed by chemical action.

Voltaic is formed from *Volta*, the name of an investigator in this field, and *ic*, pertaining to.

1. We have noticed *muscular force, gravitation, gravity, cohesion, adhesion, heat, light, magnetism, frictional electricity, and Voltaic electricity.*

2. Muscular force, gravitation, magnetism, frictional electricity, and Voltaic electricity act upon masses of matter.

Inf. 3. These may be called *molar* forces.

3. Cohesion, adhesion, and heat act upon molecules.

Inf. 4. These may be called molecular forces.

4. Gravity and gravitation (magnetism and frictional electricity sometimes) tend to bring bodies together.

5. Adhesion and cohesion hold molecules together.

6. These have been called *molecular attraction.*

4. CORRELATION OF FORCES.

EXPERIMENT 21.

Obs. At first the cent felt cool, but after the rubbing it felt warm.

Inf. The heat was produced by the rubbing.

1. Muscular force was applied in this experiment.

2. Heat was developed by it.

3. Heat is developed by friction on the axles and brakes of cars and carriages, and in the use of gimlets, bits, knives, planes, and other tools.

EXPERIMENT 22.

Obs. 1. It consists of wood, with about one fourth of an inch of the lower end coated with brimstone, and the very end tipped with a preparation containing phosphorus.

Obs. 2. The phosphorus begins to burn with a pale yellowish flame; then the sulphur burns with a pale blue flame, and finally the wood, with a yellow flame.

Obs. 3. The flame feels hot.

Inf. 1. Heat was developed by the rubbing.

1. The burning immediately followed the rubbing.

Inf. 2. Chemical affinity must have caused the new combinations of matter.

Inf. 3. The heat aided the action of this force.

Inf. 4. Heat is developed by the action of chemical affinity. This fact is inferred, because heat was manifest as soon as chemical affinity acted.

Inf. 5. By the action of this heat chemical affinity is made to act further in the burning of the sulphur and the wood.

Inf. 6. The amount of heat developed in this chemical action is much greater than that used in starting the action.

2. In Experiment 22, muscular force produced some heat; this started the action of chemical affinity in the burning of the phosphorus, by which sufficient heat was produced to continue the action of chemical affinity in burning the sulphur and then the wood; and this action produced more heat.

Inf. 7. In the use of a locomotive to move a train of cars, chemical affinity acts first in the fire-box.

Inf. 8. By this action heat is produced.

Inf. 9. The heat changes the water in the boiler into steam, which by its pressure moves the train.

Mechanical is from the Greek $\mu\eta\chi\alpha\nu\eta$, machine, and $\alpha\lambda$, pertaining to; *i. e.*, pertaining to a machine.

3. The heat produced in the fire is converted into a mechanical force.

4. Lightning is the action of electricity.

5. Buildings are often set on fire by being struck by lightning.

Inf. 10. Heat must have been developed in order to produce this effect.

6. In this case electricity produced heat, heat caused chemical affinity to act, this action produced heat, and the heat produced light.

Inf. 11. In producing electric light for towns, chemical action, heat, mechanical force, electricity, heat, and light act in that order.

Correlation is from the Latin *cor*, with, or together, *re*, again, *ferre*, *latum*, to bring, and *ion*, the act of.

5. MOLECULAR ATTRACTION.

Cohesion and *adhesion* are two forms of molecular attraction.

Cohesion is the force which holds molecules of the same substance together, and adhesion is the force that holds molecules of different substances together.

SOLUTION AND CRYSTALLIZATION.

EXPERIMENT 23.

Obs. Solid pieces of alum form on the string, and on the inside of the tumbler.

1. The alum was solid.

2. The water was liquid.

3. The alum became liquid in the hot water.

Solution is from the Latin *solvere*, *solutum*, to loosen, dis-

solve, and *ion*; *i. e.*, the act of loosening or dissolving, or that which is loosened or dissolved.

Inf. 1. Adhesion must have acted to hold the molecules of alum and water together.

Inf. 2. Cohesion must have been overcome in forming this solution.

4. Heat was applied to aid the solution.

5. When this force disappeared, some alum became solid again.

Inf. 3. Cohesion must have acted to bring the particles of alum together again.

Inf. 4. In this experiment heat acts in opposition to cohesion.

6. The solids formed from this solution had plain faces.

Crystals are solids bounded by plain faces, and formed by solidifying from solutions.

Crystal is from the Greek *κρύσταλλος*, *ice*, or crystal.

Crystallization is from the above root, with the termination meaning the act of forming.

CAPILLARY ATTRACTION.

EXPERIMENT 24.

Obs. 1. The water rises in the angle between the plates; and the smaller the angle, the higher it rises.

Inf. 1. There is an attraction between the glass and the particles of water; and where the plates are near together, nearly all the water between them is affected.

Obs. 2. The water is depressed around the plates, and more where the plates are near together.

Inf. 2. The particles of oil and water repel each other.

EXPERIMENT 25.

Obs. Water and alcohol rise in the tubes; and the smaller the tubes, the higher they rise.

Oil and mercury are lower in the tubes than outside; and the smaller the tubes the more the liquids inside are depressed.

Inf. There is an attraction between the glass of the tubes and the particles of water and alcohol; and the smaller the tube, the nearer the liquids will be to the glass, and the more they will be affected by it; while the particles of mercury and glass, and of oil and glass repel each other, and the opposite effect is produced.

1. The attraction manifest in Experiments 24 and 25 is between molecules of a solid and those of a liquid.
2. It causes the liquid to rise upon the surface of the solid.

Capillary attraction is a form of adhesion between a liquid and a solid, in which the liquid rises on the surface of the solid.

Capillary is from the Latin *capillus*, hair, and *ary*, relating to, or like; *i. e.*, hair-like.

Attraction is from the Latin *ad*, to, *trahere*, *tractum*, to draw, and *ion*; *i. e.*, the act of drawing to or together.

ABSORPTION OF GASES.

EXPERIMENT 26.

FILTER.

Obs. 1. Ammonia has a strong, pungent odor.

Obs. 2. The liquid works through the paper, and drops into the bottle.

Obs. 3. The filtrate does not smell strongly of ammonia, but the charcoal does.

Inf. 1. The ammonia gas has gone from the liquid into the charcoal.

Inf. 2. The charcoal takes the gases out of the liquids.

Inf. 3. Adhesion acts here.

Deodorizer is formed from the Latin *de*, away, *odor*, odor, *ize*, make or give, *er*, that which; *i. e.*, that which makes (takes) away odor.

Inf. 4. A drop of oil spreads over paper because there is an attraction between the molecules of the oil and those of the paper.

1. The oil of a lamp burns at the top of the wick.

Inf. 5. It is drawn up by the attraction between the molecules of the oil and those of the wick.

6. MOLAR FORCE.

a. IMPULSIVE AND CONSTANT.

1. The force with which a bat strikes a ball acts only for an instant, while the force which draws the ball downward acts continuously.

An impulsive force is one which acts only for an instant.

Impulsive is from the Latin *in*, against, *pellere*, *pulsus*, to strike, and *ive*, having the quality of, or tending; *i. e.*, tending to strike against. A striking force acts only for an instant.

A constant force is one which acts continuously.

Constant is from the Latin *constare*, *constans*, standing firm; *i. e.*, unchanging.

2. The pressure of steam in a boiler is a constant force.

3. The attraction of two bodies for each other is a constant force.

4. Force applied by a blow is an impulsive force.

b. TENDENCY OF FORCE.

EXPERIMENT 27.

Obs. The ball moves upward more and more slowly, stops and moves downward, slowly at first, but gradually faster.

Inf. 1. Muscular force of the arm produced the motion.

Inf. 2. Gravity caused the changes in the motion.

1. Molar force does not always cause motion, or change of motion.
2. One may press downward upon a table, and the table will not move.
3. Gravity draws the table down, but the table does n't move.

Inf. 3. The *tendency* of molar force is to produce motion, or change in motion.

c. VELOCITY OF MOTION.

A train of cars goes thirty miles an hour.

A man walks three miles an hour.

Inf. 1. Call the rate of motion of a body its *velocity*.

Velocity is from the Latin *velox*, swift, and *ity*, the quality of; *i. e.*, the quality of being swift.

3. An hour is a unit of time.
4. Eight miles is a distance.
5. We stated the distance which the train passed in a unit of time.
6. The earth turns *equal* distances in successive hours.
7. Uniform velocity is a rate of motion at which a body passes over equal distances in successive units of time.

Uniform is from the Latin *unus*, one, and *forma*, form, manner, kind; *i. e.* of one kind.

8. When a train is getting under way or coming to a stop, it passes over different distances in successive seconds.
9. Variable velocity is a rate of motion at which a body moves over a different distance in each successive unit of time.

Variable is from the Latin *varius*, of divers colors, different, and *able*, able to be.

Here the sense seems to be (continually) being different.

10. Accelerated velocity is a rate of motion at which a body passes over a greater distance in each successive unit of time.

Accelerated is from the Latin *accelerare* (from *ad* and *celer*, swift), to hasten; *i. e.*, hastened.

11. Definition on the same plan as for accelerated velocity.

Retarded is from the Latin *retardare* (from *re*, back, and *tardus*, slow), to delay; *i. e.*, kept back.

12. There are few cases of perfectly uniform motion.

The rotation of the earth and other planets are, perhaps, instances.

There are numerous cases of nearly uniform motion.

13. Bodies fall, a sled moves the first part of its course down a hill, and a carriage starts, with accelerated velocity.

14. A ball thrown, a train of cars, a carriage, or a steamer coming to a stop, moves with retarded velocity.

Inf. 2. An impulsive force acting alone produces uniform velocity.

Inf. 3. A constant force acting alone produces accelerated velocity.

Inf. 4. An impulsive and a constant force acting together in opposite directions will at first produce retarded motion in the direction of the impulsive force, if that force is stronger, for the instant, than the constant force.

d. MOMENTUM.

EXPERIMENT 28.

1. There is half as much motion in a second in the first case as in the second case.

Momentum is from the Latin *movēre*, to move, and *mentum*, the act of; *i. e.*, the act of moving, or movement.

Inf. The momentum of a body depends upon its velocity.

EXPERIMENT 29.

1. There is two or three times as much movement of matter in a second in the second case as in the first.

Inf. The momentum of a body also depends upon the weight of the moving body.

e. INERTIA.

Inf. 1. A moving body could never change its velocity or direction of motion unless acted upon by some force.

Inertia of motion is the inability of a moving body to change its motion.

Inertia is from the Latin *in*, not, *ars*, art or ability, and *ia*, the quality of; *i. e.*, the quality of not having ability.

Inf. 2. Call the inability of a body at rest to move *inertia of rest*.

Inertia of rest is the inability of bodies at rest to move.

Inf. 3. The man fell overboard, because the boat stopped suddenly, and the man's body could n't stop of itself, and he did n't have time to stop it.

Inf. 4. The body of a person on a moving car is moving at the same rate as the car; and when he steps upon the ground the motion of his feet may stop suddenly, and he be thrown forward.

Inf. 5. He should face in the direction in which the car is moving, and when he touches the ground take a few steps forward, until he can stop the motion of his body.

Inf. 6. A car started suddenly, and many of the standing passengers were *thrown backward*.

Inf. 7. Their feet were suddenly carried forward, and their bodies were left behind.

Inf. 8. The inertia of rest cannot be overcome all at once.

Inf. 9. The inertia of motion is too great to be overcome all at once.

1. There is a terrible wreck. The inertia of motion is immense, and cannot be overcome all at once.
2. In driving a nail, the force, as it is applied to the nail, is the inertia of the hammer.

Inf. 10. By sudden blows the carpet is forced away, and the dust is left behind, on account of its inertia of rest.

f. RESISTANCE.

OF THE AIR.

EXPERIMENT 30.

Obs. More force is required for the second movement.

Inf. 1. The air hinders the motion more in the second case. Resistance is that which hinders motion.

Resistance is from the Latin *re*, again (against), *sistere*, to stand, and *ance*, the act of; *i. e.*, the act of standing against.

Inf. 2. It is really due to the *inertia* of the air.

OF INERTIA.

Inf. 3. The greater part of the resistance in starting a train of cars is due to *inertia*.

Inf. 4. The amount of this resistance depends upon the *weight* of the cars.

OF FRICTION.

EXPERIMENT 31.

Obs. Force is required to continue the motion, after the inertia of rest has been overcome.

Inf. The motion is hindered by the rubbing of the book upon the carpet.

OF MUSCULAR FORCE.

EXPERIMENT 32.

Obs. More force is required than in Experiment 31.

Inf. This difference is due to the resistance of muscular force applied by the fingers.

OF GRAVITY.

EXPERIMENT 33.

Inf. 1. The resistance is due chiefly to gravity.

Inf. 2. The surplus force which gravity does not resist is used in overcoming the inertia of rest, and producing motion upward.

Inf. 3. All of this surplus will be used up in this way.

Inf. 4. The sum of all the different forms of resistance equals the force resisted.

Inf. 5. The direction of the resistance is opposite that of the moving force.

Inf. 6. By *action* Newton means moving force, and by *reaction*, the various forms of resistance.

g. MEASURE OF FORCE.

EXPERIMENT 34.

The facts observed under this experiment will vary with the book and the spring.

The common unit used for the measure of gravity in this country is the *pound*. The gram is used to a slight extent.

EXPERIMENT 35.

1. The force that will hold up one pound is half as great as one that will support two pounds, and one fifth as great as one that will support five pounds.

h. WORK.

Inf. 1. In drawing a double runner up hill, *inertia of rest*, *friction*, *gravity*, and *resistance of the air* must be overcome.

Inf. 2. *a.* The work of raising a pound one foot is one fourth of the work of raising it four feet.

b. It is one tenth of that of raising it ten feet.

c. It is one fourth of that of raising two pounds two feet.

d. It is one thirtieth of that of raising three pounds ten feet.

1. In measuring work, the weight and the distance it is to be raised must be considered.
2. The unit of work with which we have compared the work in these cases is that of raising one pound one foot.
3. The number of foot-pounds in the above cases was four, ten, four, thirty.

i. POWER.

Inf. 1. A locomotive can do more work than a horse in an hour.

Power is the rate at which an agent can do work.

Inf. 2. In measuring power, both the *work done* and the *time* occupied in doing it must be considered.

A horse-power is a rate of 550 foot-pounds of work per second.

1. An engine of one horse-power can raise 275 pounds two feet in a second.
2. It can raise 1,100 pounds six inches in a second.
3. It can raise 1,100 pounds five feet in ten seconds.
4. A twenty horse-power engine can raise 1,100 pounds ten feet in a second.

j. ENERGY.

Energy is ability to do work.

Energy is from the Greek *έν*, in, and *έργον*, work.

k. COMPOSITION OF FORCES.

EQUILIBRIUM.

EXPERIMENT 36.

Equilibrium is from the Latin *æquus*, equal, and *librare*, to weigh; *i. e.*, condition of equal weight, or even balance.

Resultant.

1. The two leads act in the same line.
2. They act in the same direction.

Obs. The single force which will produce the same effect (balance the sand) is the weight of a three-inch lead.

A resultant of two or more forces is a single force which will produce the same effect as the two or more forces acting together.

Resultant is from the Latin *resultare*, *resultans* (from *re*, again, back, and *salire*, to leap).

Components.

The components of a force are two or more forces which, acting together, will produce the same effect as the given force.

Component is from the Latin *com*, together, and *ponere*, *ponens*, to put.

Two Forces in the Same Line.

IN THE SAME DIRECTION.

Inf. 1. The resultant of two forces acting in the same line in the same direction is a single force equal to their sum acting in the same line in the same direction.

Inf. 2. A boat rowed down stream four miles an hour, and carried by the current two miles an hour, proceeds at the rate of six miles an hour.

IN OPPOSITE DIRECTIONS.

EXPERIMENT 37.

Obs. The resultant is a four-inch lead.

1. This is the resultant of two forces acting in the same line in opposite directions.

2. It equals the difference of the forces, and acts in the same line in the direction of the greater.

Inf. 1. The actual rate of progress is five miles an hour.

Inf. 2. It would take, approximately, four hours and forty minutes to go twenty-eight miles.

Two Parallel Forces.

IN SAME DIRECTION.

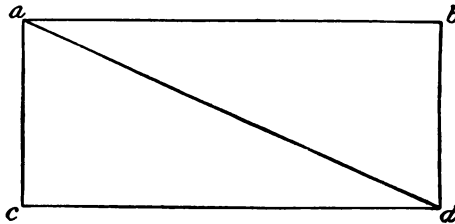
EXPERIMENT 38.

Obs. The two weights will balance an eight-inch lead supported from the screw-eye, three inches from the end screw-eye, to which the six-inch lead is attached.

Inf. 1. The resultant of two parallel forces acting in the same direction is a single force equal to their sum.

Inf. 2. Their resultant is a force of 300 pounds acting in the same direction, in a line one half as far from the line of the greater force as from the line of the smaller.

Two Forces at an Angle.



1. In twenty seconds the boat will have been carried across the river 120 feet, and down the river 60 feet.
2. The figure is a parallelogram, with a diagonal represented.
3. The diagonal represents the direction and distance of the actual motion.

4. The side $a b$ represents the direction in which the rowing would have carried the boat, and the distance it would have gone in three seconds without any current.

The side $a c$ represents the direction and distance of the motion which would have resulted from the current without the rowing, in three seconds.

Inf. The resultant is less than the sum, and greater than the difference of the components.

5. Its direction lies within the angle whose sides represent the directions of the components.

VI. GRAVITY.

2. CENTRE OF GRAVITY.

EXPERIMENT 39.

The centre of gravity of a body is the point at which the body may be supported in any position.

3. LINE OF DIRECTION.

The line of direction of a body is a vertical line passing through the centre of gravity of the body.

4. EQUILIBRIUM.

a. OF A BODY SUPPORTED AT ONE POINT.

EXPERIMENT 40.

Obs. 1. It is in equilibrium in every position.

Obs. 2. It is in equilibrium when the centre of gravity is directly above or directly below the point of support.

STABLE EQUILIBRIUM.

Obs. 3. The support is above the centre of gravity when the greatest force is required to overturn the body.

Inf. 1. With the body in this position, it (its centre of gravity) must be lifted more to overturn it.

Stable is from the Latin *stare*, to stand, and *able*, able; *i. e.*, able to stand.

UNSTABLE EQUILIBRIUM.

Obs. 4. The support is applied below the centre of gravity when least force is required to overturn the body.

Inf. 2. With the body in this position, a movement in either direction lowers it (its centre of gravity), and it is no longer supported, but falls over. It does not need to be raised at all to overturn it.

Unstable is formed like *stable*, with the prefix *un*, not; *i. e.*, not able to stand.

NEUTRAL EQUILIBRIUM.

Obs. 5. The support is applied at the centre of gravity when the body is balanced in any position.

Neutral is from the Latin *neuter*, neither; *i. e.*, neither inclined to stand nor to fall.

b. OF A BODY RESTING ON ITS BASE.

1. A book is in most stable equilibrium when it lies upon one side.

Inf. 1. In this position its centre of gravity would have to be raised most to overturn it.

Inf. 2. With the book standing on one end, its centre of gravity would have to be raised least to overturn it.

Inf. 3. A tall body is less stable than a short body, because it (its centre of gravity) would have to be raised less to overturn it.

Inf. 4. A body with a large base is more stable than one with a small base, because it (its centre of gravity) would have to be raised more to overturn it.

Inf. 5. That a body may be as stable as possible, its line of direction must pass through the centre of the base.

Inf. 6. If the line of direction passes outside the base, the body will not stand.

Inf. 7. The stability of a body resting on its base depends upon its height (the height of its centre of gravity), the size of its base, and the nearness of its line of direction to the centre of the base.

Inf. 8. The legs of chairs and stools are made to slant outward, to make the base larger, and so make them more stable.

Inf. 9. The line of direction passed within the base.

Inf. 10. The step-ladder fell over, because the centre of gravity (of the young lady *and* the step-ladder) changes as she mounts the steps, and soon the line of direction falls outside of the base.

5. FALLING BODIES.

Inf. 11. Gravity causes bodies to fall.

1. Gravity is a constant force.

Inf. 12. A body will fall for a time through the air with accelerated velocity.

EXPERIMENT 41.

Obs. The body falls with *increasing velocity*.

1. This agrees with the inference.

6. PENDULUM.

EXPERIMENT 42.

Obs. The weight swings to and fro.

A pendulum is a body suspended from a fixed point so as to swing freely.

Pendulum is from the Latin *pendulus*, from *pendere*, to hang, *i. e.*, a little hanging body.

A vibration is a single swing of the pendulum.

Vibration is formed from the Latin *vibrare*, to move to and fro, and *ion*, the act of.

b. CAUSE OF VIBRATION.

Inf. Gravity carries the pendulum downward through the first half of its swing, and its inertia of motion carries it onward, until that is overcome by gravity. Then it swings back from the same causes, and so continues.

c. RATE OF VIBRATION.

EFFECT OF LENGTH OF ARC.

EXPERIMENT 43.

Obs. 1, 2. The number of vibrations will depend upon the length of the pendulum.

Inf. The rate of vibration is not affected by the length of the arc through which the pendulum swings.

EFFECT OF WEIGHT OF PENDULUM.

EXPERIMENT 44.

Obs. Depend upon the length of the pendulum.

Inf. The weight of the pendulum does not affect the rate of vibration.

EFFECT OF LENGTH OF PENDULUM.

EXPERIMENT 45.

Obs. 1. The rate of vibration is diminished.

Obs. 2. The rate of vibration is half as great.

EXPERIMENT 46.

Obs. 1. The pendulum that makes one swing in a second is 39+ inches long.

Obs. 2. The pendulum that vibrates half seconds is 10-inches long.

USE OF PENDULUM.

1. A pendulum makes the same number of vibrations in each minute.
2. It vibrates *regularly*.
3. Hence it is adapted to measuring time.

A metronome is a pendulum used to indicate the time of a piece of music. It makes one swing for each part of the measure. It often consists of a simple string or tape, and a weight attached to one end.

Metronome is from the Greek *μέτρον*, measure, and *νέμειν*, to distribute.

USE IN CLOCKS.

Obs. Connected with the upper end of the pendulum rod is a curved bar called the escapement, with its ends bent downward so as to form little hooks. This escapement is directly over one of a series of toothed wheels which form the works. About a small shaft in the works is a steel spring, which is coiled up by turning the shaft by means of the clock key.

Inf. 1. The coiled spring tends to unwind.

Inf. 2. The spring is so connected with the works that the uncoiling of it turns the wheels of the works.

Inf. 3. If there were no pendulum, the spring would uncoil and the works move rapidly for a short time.

Inf. 4. When the pendulum swings to the right, the left end of the escapement comes down against a tooth of the wheel; and when the pendulum swings to the left, the right end of the escapement comes against another tooth. Between the letting go of one end of the escapement, and the striking of the other end, the wheel turns just one notch.

The use of the pendulum is to regulate the movement.

7. PRESSURE OF LIQUIDS.

a. FACT OF PRESSURE.

EXPERIMENT 48.

Obs. 1. The rubber swells outward.

Inf. 1. The water presses it out.

b. DIRECTIONS OF PRESSURE.

Obs. 2. The rubber swells out laterally.

Inf. 2. The water presses it laterally.

Obs. 3. The rubber swells upward.

Inf. 3. The water presses it upward.

Inf. 4. Water at rest presses in all directions.

c. UPON WHAT PRESSURE DEPENDS.

EXPERIMENT 49.

Obs. The lower the rubber is below the surface of the water the farther it swells out.

Inf. The pressure at any point in a liquid at rest depends upon the distance of the point below the surface of the liquid.

EXPERIMENT 50.

Obs. 1. The water spurts out from the tube.

Obs. 2. The lower the chimney the farther the water is thrown from the tube.

Inf. The water in the chimney presses in all directions, and forces the water out of the tube. The lower the chimney the greater the pressure, and the farther the water will be thrown.

d. SURFACE OF LIQUID IN COMMUNICATING VESSELS.

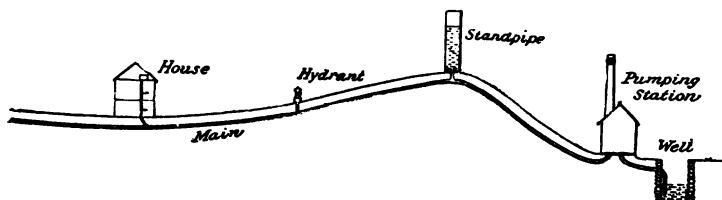
EXPERIMENT 51.

Obs. 1. The water rises to the same height in the glass tube as in the tunnel.

Obs. 2. The water remains at the same level in the glass tube and the tunnel.

e. WATER WORKS FOR CITIES AND TOWNS.

In my town the water supply is furnished from large wells. It is pumped by steam pumps at the pumping



station, and forced through a pipe to the stand-pipe, which is located on the top of a high hill. From the stand-pipe the water goes out through the large pipes, or mains, in the streets, and from the mains through small pipes into the houses and rooms where it is wanted. At intervals along the mains are located hydrants, to bring the water to the surface in the streets for use in extinguishing fires.

Inf. 1. The pressure is greatest at the lowest points in the pipes.

Inf. 2. The water would rise in the pipes of a house as high as it is in the stand-pipe.

Inf. 3. Water would be thrown highest from a hose connected with a hydrant in the lowest part of the town.

f. SPIRIT LEVEL.

Obs. 1. The spirit level consists of a slightly curved, short glass tube, nearly filled with a liquid and closed, and a case of wood, in the upper side of which the tube is set, so that the middle of the bend is the highest part when the case is exactly horizontal.

Inf. Alcohol is better than water for this use because it is not likely to freeze and break the tube.

Obs. 2. When the bubble is in the middle of the tube, the case is level, or in a horizontal position.

1. Placing the level in a horizontal position, one looks along the top of it over other surfaces and lines to determine whether they are level.

g. SPRINGS AND WELLS.

Of the water that falls upon the land as rain, some evaporates, some flows down the slopes, and some sinks into the ground.

Inf. 1. Water will fill the lower part of the hole.

Inf. 2. The water in the hole will be on the same level as in the loose material on the sides of the hole.

ARTESIAN WELLS.

The water which falls upon the exposed portion of the layer of loose material settles down to the impervious stratum, works its way down the slope of this layer, and fills the loose material above it.

Inf. 1. The water would flow out at the surface.

Artesian is from *Artesium*, the ancient name of Artois. France, where many of these wells have been made.

Inf. 2. Gravity acts to produce springs and wells.

h. FLOATING AND SINKING.

EXPERIMENT 52.

Obs. 1. A part of the water runs over into the pan, and the spring contracts.

Inf. 1. A volume of water equal to the volume of the stone is displaced.

Inf. 2. By being immersed in the water the pebble has lost of its weight. (Depends upon its size.)

Obs. 2. The spring is stretched just as much as before the pebble was immersed.

Inf. 3. The weight of the pebble in water, together with the weight of the water displaced, equals the weight of the pebble in air.

Inf. 4. The loss of weight of a solid immersed equals the weight of an equal volume of the liquid.

Inf. 5. A solid having the same weight as its own volume of the liquid will lose all of its weight on being immersed.

Infs. 6, 7. It will float at any level.

Inf. 8. A body heavier than water will sink in water.

Inf. 9. A body lighter than water will float.

Inf. 10. It will project above the liquid.

Inf. 11. A body half as heavy as water will float with half its volume above the water.

Inf. 12. Tin pans and iron ships are hollow, and may displace a volume of water equal to many times the volume of the material of which they are made.

i. SPECIFIC GRAVITY.

Specific is from the Latin *species*, a particular kind, and *facere*, to make.

a. Find the loss of weight of the iron on being immersed in water.

b. Divide the weight in air by the loss of weight in water.

Inf. 13. If a body floats with half its volume under water, its specific gravity is one half.

Inf. 14. If it floats with one eighth of its volume under water, its specific gravity is one eighth.

Inf. 15. If it floats with five sixths of its volume out of water, its specific gravity is one sixth.

8. PRESSURE OF AIR.

a. FACT OF PRESSURE.

EXPERIMENT 54.

Obs. 1. The rubber is hollowed downward.

Inf. 1. The air presses it downward.

b. DIRECTIONS OF PRESSURE.

Obs. 2. The rubber is curved upward.

Inf. 2. The air presses it upward.

The rubber hollows inward with the pipe in any position.

Inf. 3. The air presses in all directions.

c. EFFECTS OF PRESSURE.

EXPERIMENT 55.

Obs. The card-board keeps its place, and the water remains in the tumbler.

Inf. The pressure of the air upward against the card-board supports the water in the tumbler. The card-board keeps the air from mingling with the water, and maintains an even surface of the water for the air to press against.

EXPERIMENT 56.

Obs. The water remains in the tube.

Inf. The air presses up against the surface of the water and sustains it. The tube is too small to allow the air and water to mingle.

EXPERIMENT 57.

Obs. The water continues to fill the tumbler.

Inf. 1. The downward pressure of the air upon the surface of the water outside of the tumbler keeps the water from coming down out of the tumbler and rising on the outside.

Inf. 2. Gravity causes the pressure of the air.

BAROMETER.

EXPERIMENT 58.

Obs. 1. The mercury nearly fills the tube.

Inf. 1. See *Inf.* 1., Exp. 57.

Inf. 2. The pressure of the air is not great enough to sustain a column of mercury as high as the tube.

Obs. (Heights will vary at different times.)

Inf. 3. The height of the mercury column depends upon the amount of atmospheric pressure.

Inf. 4. The variation in the height of the mercury column indicates that the pressure of the air varies.

Barometer is formed from the Greek *βάρος*, weight, and *μέτρον*, measure.

EXPERIMENT 59.

Obs. The falling of the mercury in the barometer is frequently accompanied by rain and warmer temperature, while winds and clearing, cooler weather often come with a rising barometer.

Inf. When the "barometer falls," the weather is likely to be rainy and warmer; and when the "barometer rises," cooler, clearing weather is likely to follow.

PUMPS.

LIFTING PUMPS.

Suggestion.

Glass tubing about one inch in diameter and having a more even bore than the lamp chimneys may be obtained of dealers in chemical apparatus. If cut into convenient lengths, this will be better than the chimneys for making pumps.

EXPERIMENT 60.

Obs. The water follows the piston, and fills the lower part of the tube.

Inf. The air, pressing downward upon the surface of the water, forces it upward into the tube.

EXPERIMENT 61.

Obs. 1. As the piston is raised, the valve in the piston is closed and the lower valve is open. As the piston is lowered, the upper valve is open and the lower valve is closed.

Inf. 1. As the piston is raised more room is given to the air below it, and the upward pressure of the air against the valve becomes less than the downward pressure of the outside air upon the valve. At the same time this greater pressure of the air upon the surface of the water outside forces the water up into the tube, pushing the air in the tube upward and opening the lower valve. As the piston goes down, the room below it becomes less and the pressure becomes greater than that of the outside air, pressing the lower valve down and opening the upper one.

Obs. 2. As the piston is raised, water comes up through the tube and the lower valve, and the water above the piston (if any) is lifted higher and runs out at the spout. When the piston is lowered, the water below it passes above through the valve.

Inf. 2. The downward pressure upon the surface of the water outside forces it up through the tube into the cylinder when the pressure inside is lessened by raising the piston. When the piston goes down and the pressure in the cylinder becomes greater than that outside and closes the valve, there is no escape for the water in the cylinder except through the upper valve.

Inf. 3. The pressure of the air upon the surface of the water outside balances this column of water in the pipe.

Inf. 4. The atmospheric pressure is not great enough to sustain a higher column of water.

Inf. 5. Water could be raised about 30 feet with an ordinary lifting-pump.

FORCE PUMP.

EXPERIMENT 62.

Obs. 1. As the piston is raised, the valve at the bottom of the cylinder, or barrel, opens, and some water comes up through the tube into the barrel. As the piston goes down, this valve closes, the valve in the bottle opens, and some of the water goes through the tube into the bottle. As the working of the piston continues, the water is thrown out of the tube at *b*.

Inf. 1. As the piston is raised, the pressure of the air below it becomes less than the outside pressure upon the water, and the water is forced up through the tube into the cylinder. As the piston is pressed down, the pressure inside becomes greater than that outside, closing the valve in the cylinder, forcing open the valve in the bottle, and sending the water from the cylinder into the bottle.

Obs. 2. The upper part of the bottle is filled with air.

Inf. 2. When the water is forced into the air-chamber, the air in it is compressed. It tends to expand, and forces the water out through the tube in a continuous stream. The air forms an elastic cushion, and prevents the jar and strain upon the pump which would come in starting the motion of the water with each stroke of the piston.

Inf. 3. Force pumps are used at pumping-stations.

1. A fire-engine for throwing water consists of two force pumps which alternately force water into a large air-chamber, or dome, from which it is driven out by the expansive force of the air.

VII. SIMPLE MACHINES.**1. LEVERS.****a. DEFINITIONS.****EXPERIMENT 63.**

A lever is a bar which is turned about a fixed support to overcome resistance.

Lever is from the French *lever*, Latin *levare*, to raise.

A fulcrum is the support upon which a lever turns.

Fulcrum is Latin, from *fulcire*, to prop up.

EXPERIMENT 64.

Obs. The second book is raised.

1. In this experiment the fulcrum is between the load and the power.

b. RELATION OF POWER TO LOAD.**EXPERIMENT 65.**

Obs. 1. A six-inch lead applied at the same distance from the fulcrum will balance this load.

Obs. 2. A three-inch lead applied twice as far from the fulcrum will balance the load.

1. This power is half as great as the load.

Obs. 3. A two-inch lead applied three times as far from the fulcrum will balance the load.

2. This power is one third as great as the load.

Inf. The power required to balance a load diminishes as the distance of the power from the fulcrum increases.

Obs. 4. In each of the above positions a little greater power is required to raise the load than to balance it.

Obs. 5. In the first position the power moves the same distance as the load, in the second position it moves twice

as far, and in the third position it moves three times as far as the load.

EXPERIMENT 66.

Obs. 1. A power of 2 units applied 2 inches from the fulcrum will balance a load of 2 units placed 2 inches from the fulcrum.

Obs. 2. Applied 4 inches from the fulcrum, a power of 2 units will balance a load of 4 units placed 2 inches from the fulcrum.

Obs. 3. Applied 6 inches from the fulcrum, the same power will balance a load of 6 units 2 inches from the fulcrum.

EXPERIMENT 67.

Obs. When the load is placed twice as far from the fulcrum, the power required at any point to balance it is twice as great.

c. APPLICATIONS.

CROWBAR.

A crowbar is a lever of iron made heavier and square toward one end and cylindrical toward the other end. The heavier end is flattened to an edge, so that it may be inserted into small crevices. It is used to raise or move objects short distances.

STEELYARD.

In the steelyard the fulcrum is between the load and the power. The load is suspended from a hook attached to the shorter arm of the lever near the fulcrum. The power is applied on the longer arm at such distance from the fulcrum that it will balance the load. The weight of the load is shown by a graduated scale on the long arm, with the weights which the power will balance at certain points marked upon the scale.

The steelyard usually has two hooks, from either of which the load may be suspended. The one nearer the fulcrum is

for weighing heavy loads, and the one farther from the fulcrum for weighing light loads.

2. WHEEL AND AXLE.

b. RELATION OF POWER TO LOAD.

EXPERIMENT 68.

Obs. 1. A power of 2 units on the wheel will balance a load of 6 units on the axle.

Obs. 2. A power of a little more than 2 units will raise the load.

Obs. 3. In moving the load 1 inch the power moves 3 inches.

1. The load is applied $\frac{1}{2}$ inch from the axis.

2. The power is applied $1\frac{1}{2}$ inches from the axis.

Inf. 1. The axis of the wheel and axle corresponds to the fulcrum of the lever.

Inf. 2. The radius of the axle in this experiment corresponds to the short arm of the lever.

Inf. 3. The radius of the wheel corresponds to the long arm of the lever.

In the above experiment the power was applied three times as far from the axis as the load, and a power one third as great as the load was required to balance it.

Inf. 4. The relation of power to load in the wheel and axle is the same as in the lever.

Inf. 5. A load can be moved but a short distance with one application of a lever.

Inf. 6. With one application of the wheel and axle a load can be moved a long distance.

Inf. 7. The wheel and axle is better adapted for moving loads long distances.

Inf. 8. The lever is more conveniently and quickly applied when only a slight change of position is desired.

EXPERIMENT 69.

Obs. 1. A power of 9 units on the axle will balance a load of 3 units on the wheel.

Obs. 2. A power of a little more than 9 units on the axle will raise a load of 3 units on the wheel.

Obs. 3. In raising the load 6 inches the power moves 2 inches.

1. These results agree with those obtained in the lever.

c. APPLICATIONS.

A *windlass* is used for drawing water and raising anchors and other loads, a *capstan* is used for moving buildings, a *winch* for turning a grindstone, a bit-brace for boring holes, and a water-wheel for turning machinery.

3. PULLEYS.**a. DESCRIBE.**

A pulley is a wheel with a grooved circumference over which a cord may pass.

b. RELATION OF POWER TO LOAD IN FIXED PULLEYS.**EXPERIMENT 70.**

Obs. 1. A power of 6 units applied at the other end will balance the load.

Obs. 2. A power of a little more than 6 units will raise the load.

Inf. To raise a load, friction and inertia of rest must be overcome; therefore more power would be required than would be necessary to balance it.

EXPERIMENT 71.

Obs. A power equal to the load is required to balance a load over three fixed pulleys.

Inf. An equal power will balance any load over any number of fixed pulleys.

(If the power and load are not exactly equal, the resistance of friction may be sufficient to maintain equilibrium; and heavier weights than are suggested in the directions will be more satisfactory.)

IN COMBINATIONS OF FIXED AND MOVABLE PULLEYS.

EXPERIMENT 72.

Obs. 1. A power of 1 pound will balance the load of 2 pounds.

1. The power equals half the load.

Obs. 2. The movable pulley is supported by two parts of the cord.

EXPERIMENT 73.

Obs. 1. The power equals one third of the load.

Obs. 2. In raising the load the power moves three times as far as the load.

c. USE OF PULLEYS.

Inf. 1. Fixed pulleys change the direction of a force, and so enable us to apply the force from a more convenient position and to employ forces which would not otherwise be available.

Inf. 2. A combination of fixed and movable pulleys, in addition to the advantages afforded by fixed pulleys, enable us to raise slowly heavier loads than we otherwise could.

4. INCLINED PLANE.

a. RELATION OF POWER TO LOAD.

EXPERIMENT 74.

Obs. 1. The car runs down the plane.

Obs. 2. A power of one half pound will balance the load of three pounds.

1. It equals one sixth of the load.
2. The height of the plane equals one sixth of the length of the plane.

Inf. The power required is less than the load because the plane supports a large part of the load.

EXPERIMENT 75.

The power required to balance the load equals one third of the load, and the height of the plane equals one third of the length of the plane.

b. USE.

1. The slope of a hill is used in raising a carriage load to its summit, the grade of a railroad track is used in raising a train to a higher level, and inclined planes are used for loading heavy casks, and for raising carriages to the upper stories of buildings.

Inf. The plane supports a large part of the load, and enables a comparatively small power to raise it.

5. SCREW.

1. The general shape of the screw is cylindrical.
2. A spiral projection winds around the cylinder.
3. The upper and lower surfaces of this projection incline upward to the right, and form inclined planes.
4. In the nut there is a groove for the thread of the screw to fit into.
5. The screw rests upon the under side of the thread.
6. When the screw is turned, the under side of the thread slides over the inclined plane which forms the lower side of the groove in the nut.

6. WEDGE.

1. A wedge is shaped like a small inclined plane with its base, or like two inclined planes with their bases together.
2. It is used for splitting wood, splitting rocks, and raising loads.
3. The load is not moved over the wedge.
4. The wedge is moved.
5. It is driven with a hammer or beetle.

APPLICATIONS OF THE SIMPLE MACHINES.

1. Pulleys, wheel and axle and inclined planes are used to raise loads to the upper stories of buildings.
2. A door key is a form of wheel and axle, though it is used to move the load but a short distance.
3. The wheel and axle is used for raising and lowering the wicks of lamps.
4. The wedge is used for splitting wood.
5. A form of wheel and axle, called a capstan, is used in moving a building along the street.
6. A lever is used in working a jack-screw.
7. An inclined plane would be used in loading a barrel of oil upon a truck.
8. A long lever, called a "well sweep," and a form of wheel and axle, called a windlass, have been used for raising "the old oaken bucket" from the well.
9. In a lever the resistance of friction is less than in any other simple machine.
10. No machine can furnish energy.

VIII. HEAT.

1. SOURCES OF HEAT.

EXPERIMENT 76.

Obs. The hand feels warmer in the sunshine than in the shade.

Inf. The sun is a source of heat.

EXPERIMENT 77. (See Experiment 31.)

Inf. Friction is a source of heat.

EXPERIMENT 78.

Obs. The nail becomes heated by hammering.

Inf. 1. Hammering, or percussion, is a source of heat.

1. Two other sources of heat noticed in our study of Correlation of Forces were *chemical action* and *electricity* (lightning).

2. The sources of heat we have considered are the sun, friction, percussion, chemical action, and electricity.

Inf. 2. Most heat is derived from the sun.

Inf. 3. The next greatest source of supply is chemical action.

2. EFFECTS OF HEAT.

a. EXPANSION.

(1) OF SOLIDS.

EXPERIMENT 79.

Obs. 1. The marble drops through the heated ring.

Inf. 1. The ring has grown larger, or expanded, from the heat.

Inf. 2. One effect of heat is that it expands solids.

Expansion is from the Latin *ex*, out, *pandere*, to spread, and *ion*, the act of; the act of spreading out.

Obs. 2. The marble will not drop through after the ring is cooled.

Inf. 3. After losing its heat the wire returns to its former size.

1. Other instances of the expansion of solids are the enlarging of lamp chimneys so that they break when they become hot if they are screwed up too tightly, the breaking of tumblers, etc., when hot water is poured into them, and the sagging of telephone wires in a very hot day.
2. In laying the rails of a railroad, a space is left between the ends to allow for expansion in hot days.
3. This fact is made use of in hooping casks, etc., with iron hoops, in setting tires on wheels, in straightening brick walls by means of heated rods, and in making boilers tight by means of heated rivets.

(2) OF LIQUIDS.

EXPERIMENT 80.

Obs. 1. The water rises in the tube.

Inf. 1. The heat expands the water.

Obs. 2. The water returns to its former volume.

Inf. 2. The water loses its heat, and the cause of the expansion is removed.

EXPERIMENT 81.

Obs. 1. The mercury rises in the tube.

Inf. 1. The heat expands it.

Obs. and Inf. 2. When the bulb is cooled the mercury goes down in the tube, because when the heat is taken away the cause of the expansion is removed.

1. The thermometer consists of a glass tube with a very small bore and a bulb blown at the end. The bulb

Evaporation is from the Latin *e* (for *ex*), out, *vaporare*, to emit vapor, and *ion*, the act of.

EFFECT OF VAPORIZATION ON ADJACENT BODIES.

EXPERIMENT 88.

Obs. The water under the crystal freezes.

Inf. 1. It is caused by the evaporation of the ether.

1. Sprinkling the floor or street cools the air while the water is evaporating.

2. A summer shower cools the air in the same way.

Inf. 2. The heat required to change the water from a liquid to a vapor is taken chiefly from the surrounding air.

Artificial ice is made according to this principle: *i. e.*, that evaporation takes heat from adjacent bodies. A very large tank of brine — water saturated with salt — has running through it a set of pipes. The air in these pipes is exhausted by means of an engine, and then ammonia is introduced, which suddenly changes to gas in the vacuum. This cools the pipes to such a degree as to make the temperature of the brine much below the freezing point, the same as the salt water around an ice-cream freezer. Now set into this brine, between the pipes, are cans (shaped like the cakes of ice we wish to make) filled with clear, fresh water. Ice at once begins to form on the inside of these cans, and in forty-eight hours or so the water in the cans is entirely frozen, making solid cakes of ice. The cans, of course, are open at the top, and after exposing them to the warm air a few minutes, the cakes slide out.

CONDENSATION.

EXPERIMENT 89.

Obs. Drops of water form on the cold glass.

Inf. The vapor coming in contact with the cold surface is cooled to such a degree that it changes back to water.

1. A vapor is changed to a liquid.

Condensation is from the Latin *con*, with, *densare*, to make dense, and *ion*, the act of.

DEW, DEW POINT, FROST, CLOUDS, RAIN, HAIL, SNOW.

EXPERIMENT 90.

Inf. 1. The cool can takes heat from the vapor in the air in contact with it, and the vapor is condensed on the outside of the can.

Inf. 2. The surface of the grass cools off more rapidly than the air, and the vapor of the air is condensed on the cool grass.

Inf. 3. Frost is frozen dew.

Inf. 4. The warm air is cooled when it comes in contact with colder air.

Inf. 5. The moisture of the warm air is condensed.

Inf. 6. Rain is formed by the moisture of a warmer body of air being condensed as it comes in contact with colder air, thus forming drops, which fall.

Hail is frozen drops of rain.

Snow is frozen vapor before it has formed into drops.

3. TRANSFER OF HEAT.

a. RADIATION.

EXPERIMENT 91.

Obs. The hand feels warmer.

Inf. It receives heat from the heated body.

EXPERIMENT 92.

Obs. Heat is felt in whatever direction the hand is held from the heated body.

Inf. Heat passes in all directions from heated bodies.

EXPERIMENT 93.

Obs. Not much heat is felt.

Inf. 1. Heat passes in straight lines from heated bodies.

Radiation is from the Latin *radiare*, to emit rays, and *ion*.

Radiator is from *radiare*, and *or*, that which.

Fire screens protect against the radiated heat in directions where the heat is not wanted.

b. CONDUCTION.

EXPERIMENT 94.

Obs. The marble nearest the flame dropped off first, then the one next, and so on, until all had melted off.

Inf. 1. Heat is carried from the flame through the rod, thus melting the wax.

Conduction is derived from the Latin *conducere*, to lead, and *ion*, the act of.

GOOD AND POOR CONDUCTORS.

EXPERIMENT 95.

The heat is conducted more readily through the iron than through the slate.

Conductor is derived from *conducere*, to lead, and *or*, that which.

USES OF POOR CONDUCTORS.

EXPERIMENT 96.

Obs. 1. The temperature of all the bodies is the same.

Obs. 2. They do not *feel* equally warm.

Inf. 1. Some of them — the iron, for instance — conduct the heat from the cheek more rapidly than some of the others, as the woollen.

Inf. 2. Clothing is necessary to prevent the heat of the body from passing off too rapidly.

Inf. 3. The best material for clothing is wool.

1. Sawdust, shavings, powdered charcoal, etc., in the walls of ice chests and ice houses, keep the outside heat from getting in. The wrappings around steam pipes where steam is to be carried some distance through pipes keeps the heat from passing off.

WATER AS A CONDUCTOR.

EXPERIMENT 97.

Obs. The water in the lower part of the tube is not heated.

Inf. Water is a poor conductor.

The fact that air is a poor conductor is made use of in constructing houses and refrigerators by having an air space in the walls, which keeps heat from passing through, either in or out.

WEIGHT OF HOT AND COLD WATER.

EXPERIMENT 98.

Obs. The hot water is lighter than the cold.

Inf. The hot water is expanded so that there is really not so much of it as of the cold water in the can.

c. CONVECTION.

EXPERIMENT 99.

Obs. The particles of sawdust move away from the heated place, and other particles move in to take their place.

Inf. 1. The water which becomes heated is expanded, and made lighter than the water around it, so that the heavier water crowds under the lighter by force of gravity,

and forces it away. This in turn becomes heated, and is forced away in the same manner.

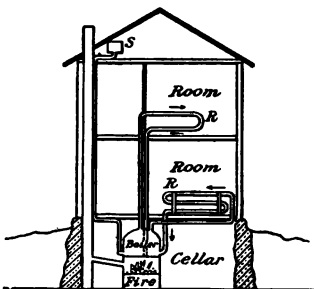
Inf. 2. Ocean currents are caused by the unequal heating of different parts of the ocean. The equatorial waters become heated by the sun, and the colder, heavier waters flow in under them and force them away, thus forming currents in a manner similar to what we saw in the pan of water, but on a grander scale.

EXPERIMENT 100.

Obs. The water moves rapidly through the tube, and is replaced with water from the test tube.

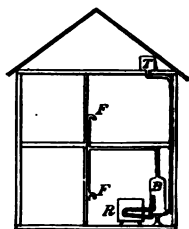
Inf. The portion in the flame becomes heated, and is forced upward by the cooler water.

1. A furnace has in the upper part a strong boiler with pipes leading to the rooms to be heated, and thence back again to the boiler. Another pipe from a tank (*S*) in a part of the house higher than any part to be heated, serves to communicate pressure and to relieve the expansion of the water, as it is heated. The pipes and boiler are filled with water, and as it becomes heated it begins to circulate through the pipes leading to the rooms, as we saw it circulate in the glass tubing in the last experiment. This circulation of hot water warms the rooms from the radiating pipes (*R*) in each room.



NOTE. — The diagrams and explanations for *heating by hot water*, and those which follow in the *furnishing of hot water from a kitchen range*, and *heating by furnace*, only explain the principles which are essential in the endless variety in use.

R is a kitchen range, *B* the copper cylinder, or boiler. This is supplied with water by a pipe from the tank (*T*) in the upper part of the house, the cold water from the tank being taken in at the base of the boiler. A pipe also leads out of the base of the boiler, through the range close to the fire, and turns back into the boiler and runs up toward the top, inside. Other pipes lead out from the top of the boiler to different parts of the house, where the warm water may be drawn from faucets (*F*). The supply pipe keeps the boiler and all the pipes always full, and furnishes pressure to carry the water to all parts of the house. The water in the short pipe in the range becomes hot, and is rapidly forced through by cooler water from the lower part of the boiler. Thus a constant circulation is maintained, keeping the water in the boiler always hot. The water in the pipes which supply the rooms becomes cooled when the pipes are not drawn from; but after running a little this cooler water is drawn off, and hot water from the boiler is supplied.



DRAUGHTS.

EXPERIMENT 101.

Obs. 1. The end of the paper moves upward.

Obs. 2. The end of the paper moves upward.

Inf. The air inside the chimney, becoming heated, is forced upward by the denser cool air from outside, which crowds in, and this in turn becomes heated, and thus creates a constant current or draught of air.

EXPERIMENT 102.

Obs. There is a draught through the flue of an oil stove.

Inf. 1. It is produced by the heating of the air in the

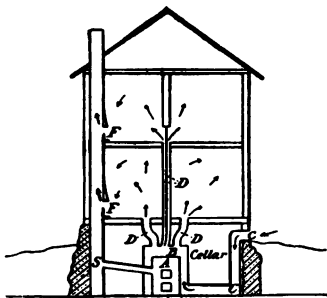
passages above the flame, and the flowing in of cooler, heavier air towards the place occupied by this warm, lighter air.

Inf. 2. The draught through a stove and up the chimney is precisely the same as in the oil stove and lamp chimney.

1. The air near the stove becomes warmer than the air farther away from it, and the air from the colder parts of the room moves toward the stove, and that around and above the stove moves upward. If any part of the room is colder than other portions, — as a part near a cold window, — the current toward the stove is more marked from that direction.

Inf. 3. This is caused by the heating and expanding of the air about the stove.

2. A furnace (*A*) is inclosed by brick or sheet iron, so as to form an air chamber (*B*) around the outside. This air in the chamber becomes heated, and is forced upward through the pipes (*D*) by the cooler outside air which enters through the cold-air box (*C*). Fireplaces (*F*), or some other means of allowing the air to escape from the rooms, aid in



maintaining a constant circulation of warm fresh air so essential to health in every house.

WINDS.

EXPERIMENT 103.

Obs The flame points from the cool room towards the warm one when held at the bottom of the doorway, and from the warm room towards the cool one when held at the top.

Inf. 1. This is caused by the flowing of the cold, heavier air from the cold room under the warmer air in the warm room, thus driving out the warm air through the upper part of the doorway.

Inf. 2. These draughts are produced by the action of gravity tending to make the air of different densities level.

Inf. 3. Air in different sections of the atmosphere becomes unequally heated, and the colder, denser air will always move towards the warmer, rarer portions, and they in turn give way. Thus we have produced a more or less rapid motion of air, which we call wind.

Inf. 4. Land and sea breezes are winds which blow on the sea coast during the day from the sea towards the land, and during the night from the land towards the sea. During the day the land becomes more heated than the water, and thus the air near it becomes more heated than that above the water, and the denser, colder air over the water presses towards the land. At night the land gives up its heat more readily than the water, and the air becomes colder over the land, and the winds are reversed. This is especially noticeable in extremely hot days near the sea coast.

Inf. 5. Trade winds are the constant winds of the equatorial regions, caused by the air near the equator becoming more heated than the air farther north or south; hence the cooler air sets in towards the equator. They are north-east winds in the northern hemisphere, and southeast winds in the southern hemisphere.

4. LATENT HEAT.

EXPERIMENT 104.

Obs. 1. The mercury stands at the boiling point (212° F.).

Obs. 2. The temperature remains the same.

Inf. 1. The additional heat applied is used in converting the water to a vapor.

Latent heat is the heat which disappears in melting or vaporization.

EXPERIMENT 105.

Obs. 1. The quantity of water in the flask has diminished, and that in the can has increased.

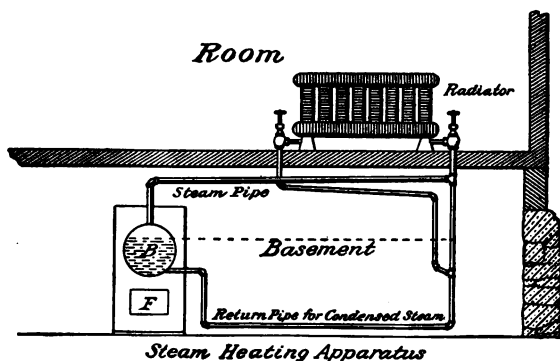
The water in the can has grown warm.

Obs. 2. The temperature of the water in the flask remains the same.

Inf. 1. The heat applied was used in changing the water to steam.

Inf. 2. The steam passed through the tube and was condensed in the can.

Inf. 3. When the vapor was condensed, the latent heat was set free, and warmed the water of the can.



Steam heating apparatus consists of a boiler (*B*) and a fire-box (*F*), similar to those of a steam engine, with steam pipes leading from the top of the boiler to the radiators in the rooms, and return pipes to carry the condensed steam from the radiators back to the lower part of the boiler.

As the temperature of the radiators is lower than that at which steam can exist (212° F.), the steam is condensed, giving out its latent heat of vaporization to the radiators, which in turn communicate it to the air of the rooms.

EXPERIMENT 106.

Obs. 1. The water is a little warmer than the ice.

Obs. 2. The contents of the test tube which contained the ice have about the same temperature as before, while the water in the other test tube has become as hot as that in the can.

Inf. 1. The heat received by the ice has been used in changing it into liquid.

Inf. 2. The deepest snow or the thickest ice would melt instantly when the temperature reached the melting point (32° F.), if no heat were absorbed as latent heat in melting.

IX. MAGNETISM.**1. MAGNETS.****b. KINDS OF MAGNETS.****TEMPORARY.****EXPERIMENT 107.**

Pupils should be cautioned to use *iron* nails — not steel wire — in this experiment.

Obs. 1. The second nail sticks to the first.

Inf. 1. The first nail has become a magnet.

Obs. 2. The second nail drops from the first.

Inf. 2. The first nail was a *temporary* magnet.

1. It was produced by being brought in contact with a magnet.

PERMANENT.

EXPERIMENT 108.

Obs. 1. The iron filings stick to the end of the wire.

Inf. 1. The wire has become a magnet.

Obs. 2. The iron filings still stick to the end of the wire.

Inf. 2. The wire is a *permanent* magnet.

1. I *infer* this fact.

2. This magnet was produced by rubbing the steel wire in one direction with the end of a magnet.

c. POLES OF A MAGNET.

EXPERIMENT 109.

Obs. The filings cling to the magnet chiefly at the ends.

Inf. The magnetism is manifest chiefly at the ends of the magnet.

EXPERIMENT 110.

Obs. The magnet points nearly north and south.

d. LAW OF MAGNETS.

EXPERIMENT 111.

Obs. When two north poles or two south poles are brought near each other, they fly apart; but when a north and a south pole are brought near each other they rush together.

Inf. Like poles repel each other, and unlike poles attract each other.

2. TERRESTRIAL MAGNETISM.

a. MAGNETIC NEEDLE.

EXPERIMENT 112.

Obs. 1. The wire magnet takes the same direction as the bar magnet.

Obs. 2. The needle changes its direction with the bar magnet.

Inf. The bar magnet controls the direction of the needle.

EXPERIMENT 113.

Inf. The earth influences the direction of the needle now.

b. MAGNETIC DECLINATION.

1. The needle points to the west of north, making an angle of 10 or 12 degrees with a north and south line.

THE MARINER'S COMPASS.

The mariner's compass consists of a magnetic needle, balanced, by means of an agate cap, upon a pivot in the centre of a cylindrical case, which is supported in such a way as to keep the needle in a horizontal position in spite of the rolling of the vessel. Attached to the top of the needle is a circular card representing the horizon, and having the cardinal points and other intervening points marked upon it.

X. FRICTIONAL ELECTRICITY.**1. HOW EXCITED.****EXPERIMENT 114.**

Obs. 1. Nothing unusual happens.

Obs. 2. The ribbon sticks to the wall.

Inf. Some force holds the ribbon to the wall.

EXPERIMENT 115.

Obs. 1. No peculiar result follows.

Obs. 2. The paper sticks to the wall.

Inf. Some force holds the paper to the wall.

EXPERIMENT 116.

Obs. The bits of paper fly to the sealing-wax.

Inf. Some force attracts the bits of paper.

1. It was excited by friction.

2. ELECTROSCOPES.

a. PITH-BALL

EXPERIMENT 117.

Obs. The pith-balls spread apart and fly to the chimney; but after touching it they fly off again.

b. BALANCED BAR.

EXPERIMENT 118.

Obs. The end of the bar comes up to the chimney.

3. KINDS OF ELECTRICITY.

EXPERIMENT 119.

Obs. 1. The pith-balls fly to the chimney, but soon fly off. After a few seconds they come to the chimney again.

Obs. 2. The pith-balls move to the sealing wax and then away, just as with the chimney.

EXPERIMENT 120.

Obs. The pith-balls move back and forth between the chimney and the sealing wax.

Inf. The pith-balls are *attracted* by the sealing wax when they are *repelled* by the chimney, and *vice versa*. The electricity in the sealing wax must be different from that in the chimney.

EXPERIMENT 121.

The end of the balanced bar is affected in the same ways in which the pith-balls were.

EXPERIMENT 122.

Negative electricity is excited in the silk pad when rubbed with the chimney, and positive when rubbed with the sealing wax.

Positive electricity is excited in the flannel when rubbed with the chimney, and the same when rubbed with the sealing wax.

4. LAW OF ELECTRICITIES.

EXPERIMENT 123.

Obs. 1. The chimney on the hooks turns away from the other.

Obs. 2. The stick of sealing wax on the hooks turns away from the other.

Obs. 3. The chimney, when on the hooks, turns toward the excited sealing wax; and the sealing wax, when on the hooks, turns toward the excited chimney.

Inf. Bodies charged with the same kind of electricity repel each other, and bodies charged with unlike electricities attract each other.

5. CONDUCTION.

CONDUCTORS AND INSULATORS.

EXPERIMENT 124.

Obs. 1. The bar is not affected.

Obs. 2. The bar is not affected.

EXPERIMENT 125.

The electroscopes are slightly affected.

EXPERIMENT 126.

The electroscopes are affected, but more when near the key.

Inf. 1. The electricities of the excited bodies act over the rule, the pencil, and the key upon the electroscope, but do not act over the glass tubing.

Glass is an insulator, the rule and the pencil are poor conductors, and the key is a good conductor.

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Positive electrode
with the negative
sealing wall

Electricity is
negative

body near
the body
the excited
the excited

Obs. 1. The
other.

Obs. 2. The
from the

Obs. 3. The
the
hooked

Obs. 4. The
regard
ties

the pith-
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at of the
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Obs. 5. The
Obs. 6. The

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Inf. 2. Glass bottles are used in electroscopes in order that the electricity may not be dissipated by acting over the electroscope upon other bodies.

Inf. 3. Pith-balls in contact with an electrified body become electrified, or charged with the same kind of electricity which is in the body, and so are repelled from the body. The two pith-balls become charged with the same kind of electricity, and repel each other.

Inf. 4. Lightning rods are electric conductors, and the electricities of the earth and the air act over them instead of over the building or through it.

6. INDUCTION.

EXPERIMENT 127.

Obs. The end of the bar moves up to the can.

Inf. Electricity must have been developed in the can by the approach of the excited chimney.

If the excited chimney is used to induce electricity in the can, and the excited sealing wax is held just beyond the electroscope in this experiment, the electroscope is attracted by the wax when it is repelled by the can, and attracted by the can when it is repelled by the wax. This indicates that the electricity at that end of the can is *unlike* the electricity of the wax. Hence it must be *positive*.

Obs. and Inf. 2. When the electroscope is brought near the other end of the can, it is affected. Hence there must be electricity at that end of the can.

Obs. and Inf. 3. If the pith-balls are placed between the chimney and the end of the can, they move from one to the other.

The electricity at that end of the can must be unlike that of the chimney. It is negative.

In the same way it may be shown that if the excited

wax is used in place of the chimney, positive electricity is developed at the end of the can near the wax, and negative electricity at the other end.

Inf. 4. The first effect of bringing an excited body near an insulated body is to develop upon the insulated body electricity of the opposite kind at the end near the excited body, and electricity of the same kind as in the excited body at the other end.

Inf. 5. The electricity developed on the side of the pith-balls or bar next to the excited body is unlike that of the excited body, and that on the other side is like that of the excited body. As the unlike electricities are nearer together than the like electricities, the attraction is stronger than the repulsion, and the bodies come together. When the bodies come in contact, the electricity on the side of the pith-balls next to the excited body is neutralized by the opposite electricity, and the pith-balls are left charged with electricity like that of the excited body, and are repelled.

XI. VOLTAIC ELECTRICITY.

1. VOLTAIC ELEMENT.

EXPERIMENT 128.

1. This Voltaic element consists of a zinc plate and a copper plate connected by a copper wire, and inserted in a solution of potassium bichromate and sulphuric acid.

2. HOW PRODUCED.

Inf. The electricity was produced by chemical action.

3. EFFECTS.

a. MAGNETIC EFFECTS.

1. Voltaic electricity changes the direction of the magnetic needle.

EXPERIMENT 129.

Obs. 1. The bits of iron stick to the end of the rod.

Obs. 2. They stick to the other end.

Inf. 1. The rod has become a magnet.

Inf. 2. The rod was made a magnet by the action of the Voltaic electricity.

Obs. 3. The iron drops from the rod when the wire is cut.

Obs. 4. The rod now attracts iron.

Obs. 5. The tack drops as soon as the ends of the wire are separated.

Inf. 3. The rod loses its magnetism as soon as the connection is broken.

1. Voltaic electricity turns the magnetic needle, and produces electro-magnets.

b. THERMAL EFFECTS.

EXPERIMENT 130.

Obs. The platinum wire feels hot.

Inf. The wire was heated by the electricity.

c. LUMINOUS EFFECTS.

1. Incandescent electric lights are produced by the action of electricity through carbon filaments, which it heats to a white heat.
2. Lightning, arc lights, and flashes of light around trolley wires and electric car rails are produced by electricity.

XII. SOUND.**1. HOW PRODUCED.****EXPERIMENT 131.**

Obs. The tine vibrates rapidly, and a sound is heard

EXPERIMENT 132.

Obs. The string vibrates rapidly, and a sound is heard.

EXPERIMENT 133.

Obs. The pencil rapidly bobs off from the bell, and falls back again.

Inf. 1. The bell vibrates and throws the pencil off.

Inf. 2. Sound is due to the rapid vibration of elastic bodies.

2. TRANSMISSION OF VIBRATIONS.**a. THROUGH WOOD.****EXPERIMENT 134.**

Obs. The sound seems to come from the door.

Inf. The vibrations of the fork are communicated to the lath, and through it to the panel of the door.

b. THROUGH A STRING.**EXPERIMENT 135.**

Obs. 1. The sound of the fork is heard plainly.

Obs. 2. The sound seems to come from the box.

Inf. The vibrations passed through the string to the box

c. THROUGH THE AIR.**EXPERIMENT 136.**

Obs. The sand dances about over the paper.

Inf. 1. The paper vibrates and shakes the sand.

Inf. 2. The vibrations of the vocal cords are transmitted through the air to the paper.

Inf. 3. The vibrations of the objects will cause the air between them and the drum to vibrate, and the vibrations will thus be communicated to the drum.

1. A man was chopping wood about a quarter of a mile from the observer, on the opposite side of a pond. When the sound of the stroke reached the observer, the axe was raised for another blow. It took about a second for the sound to be transmitted across the pond.

3. VIBRATING STRINGS.

a. LOUDNESS OF TONES.

EXPERIMENT 137.

- Obs.* 1. The string vibrates and a tone is heard.
Obs. 2. The string vibrates farther and the tone is louder.
Obs. 3. The string vibrates still farther and the tone is louder.

Inf. The loudness of a tone depends upon the amplitude of the vibrations.

b. PITCH OF TONES.

EXPERIMENT 138.

1. When a heavier string is used, the tone is lower.

Inf. Light strings produce high tones.

EXPERIMENT 139.

- 1 The tone is higher than that produced by the longer string.
2. The tone produced is still higher.

Inf. The shorter the string the higher the tone which it produces.

EXPERIMENT 140.

The tone produced by the 8-inch string is an octave above that produced by the 16-inch string.

EXPERIMENT 141.

Obs. 2. A higher tone is produced.

Obs. 3. A still higher tone is produced.

Inf. The pitch of the tone is raised by increasing the stretching force of the string.

EXPERIMENT 142.

1. The second tone is an octave above the first.
2. The length of the strings, the weight of the strings, and the stretching force affect the pitch of tones.
3. Light, short, tight strings produce high tones.
4. Long, heavy, loose strings produce low tones.
5. The strings of a piano are varied in length and weight to produce the different tones.
6. Pianos are tuned by tightening or loosening the strings just enough to produce the right tones.

4. VIBRATING COLUMNS OF AIR.**EXPERIMENT 143.**

Obs. A tone is produced.

EXPERIMENT 144.

Obs. The sand dances about the paper.

Inf. The air in the pipe is vibrating, and these vibrations are communicated to the paper and the sand.

EXPERIMENT 146.

The tone is lower than that produced by the smaller bottle.

EXPERIMENT 147.

Obs. 1. The tone is higher than that produced by the empty bottle.

Inf. 2. The vibrations of the vocal cords are transmitted through the air to the paper.

Inf. 3. The vibrations of the objects will cause the air between them and the drum to vibrate, and the vibrations will thus be communicated to the drum.

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Inf. The air in the pipe is vibrating, and these vibrations are communicated to the paper and the sand.

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EXPERIMENT 147.

Obs. 1. The tone is higher than that produced by the empty bottle.

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a. LOUDNESS OF TONES.

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Obs. 2. The string vibrates farther and the tone is louder.

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EXPERIMENT 146.

The tone is lower than that produced by the smaller bottle.

EXPERIMENT 147.

Obs. 1. The tone is higher than that produced by the empty bottle.

Obs. 2. The tone is still higher.

Inf. The longer the organ pipe the lower the tone, and the shorter the pipe the higher the tone.

EXPERIMENT 148.

Obs. The lowest tone produced by the closed pipe is an octave lower than that produced by the open pipe.

Inf. Short, open pipes produce high tones, and long, closed pipes produce low tones.

XIII. LIGHT.

1. SOURCES.

The sun, stars, and intensely heated bodies originate light.

The moon, wooden blocks, and stones, at ordinary temperatures, do not originate light.

1. All light comes originally from luminous bodies.
2. The sun and stars are natural sources of light.
3. The chief artificial sources of light are combustion and electricity.

2. TRANSMISSION.

a. MEDIUM, — TRANSPARENT; TRANSLUCENT.

EXPERIMENT 149.

Obs. The light itself cannot be seen.

EXPERIMENT 150.

Obs. Nearly or quite all of the light passes through the glass.

1. About all of it passes through the air.

EXPERIMENT 151.

Obs. Only a part of the light passes through the colored glass and the paper.

1. Pure water, alcohol, hydrogen, and oxygen are transparent media.
2. Colored liquids in small quantities, thin sheets of mica, and thin edges of some other minerals, and some varieties of china are translucent media.
3. No light will pass through an inch board or a book.

b. RAY; c. BEAM.

EXPERIMENT 152.

Obs. 1. The light passes in straight lines.

1. There are many rays thrown into the room by the *porte lumière*.

Obs. 2. These rays have the same direction.

d. PENCIL OF LIGHT.

EXPERIMENT 153.

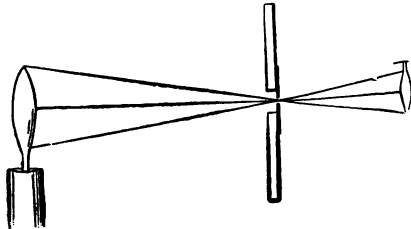
Obs. The rays beyond the lens incline toward each other, and all pass through a certain point, beyond which they diverge.

e. IMAGE BY SMALL APERTURE.

EXPERIMENT 154.

Obs. An inverted image of the candle flame is formed upon the screen.

Inf. 1. Rays from the top of the flame passing through the hole in the tinfoil strike the screen lower than those coming from other parts of the flame; rays from the



bottom of the flame strike the screen higher than the others; rays from the right of the flame strike the screen on the left; and those from the left of the flame strike the screen

on the right. Thus an inverted image of the flame is formed upon the screen.

Obs. 2. The nearer the screen is to the box the smaller the image, and the farther it is from the box the larger the image.

Inf. 2. From the above diagram it will be seen that near the box the rays have separated but little, and would form a small image upon a screen; while farther from the box they have separated more, and would form a larger image upon a screen.

EXPERIMENT 155.

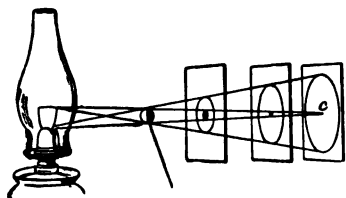
Obs. Smaller inverted images of the outside objects are formed upon the screen.

f. SHADOW, UMBRA, AND PENUMBRA.

EXPERIMENT 156.

Obs. If a little sphere is held before the flame, a dark circle smaller than the sphere is formed on the screen, and a larger concentric circle not so dark. As the screen is moved farther away, the dark circle grows smaller, and the lighter circle grows larger and less distinct.

Inf. Since the light passes from the flame in straight lines, it will all be shut off from a conical-shaped space beyond the sphere having its apex at *c*; and a portion of the light from the flame will be shut off from a space having the shape of the frustum of a cone with its base upon the screen. Thus the appearances which were seen upon the screen would be produced.



g. ECLIPSE OF THE MOON.

The moon is an illuminated body.

Its light comes from the sun.

The earth is opaque.

There must be a shadow on the side of the earth away from the sun.

The earth is smaller than the sun.

The earth's umbra must be conical.

The earth's penumbra must have the form of the frustum of a cone with the base away from the earth.

At certain times the moon passes through the earth's shadow, and is not then illuminated by the sun. It is said to be in eclipse. (See Astronomies.)

h. ECLIPSE OF THE SUN.

The umbra and penumbra of the moon are similar in form to those of the earth, but the umbra is smaller.

At certain times the moon comes directly between the sun and a part of the earth; *i. e.*, a portion of the earth comes into the moon's shadow, and a part or all of the sun is hidden, or in eclipse.

i. VELOCITY OF LIGHT.

The velocity of light = $186,000,000 \text{ miles} \div 996 = \text{more than } 186,000 \text{ miles per second.}$

j. REFLECTION OF LIGHT.**EXPERIMENT 157.**

Obs. The beam of light is turned back from the mirror.

A mirror is a smooth, polished surface.

It turns back the rays of light in regular order.

LAW OF REFLECTION.

The angle of incidence equals the angle of reflection.

DIFFUSED LIGHT.

EXPERIMENT 158.

Obs. The light is not reflected regularly.

IMAGE OF A POINT BY A PLANE MIRROR.

EXPERIMENT 159.

Obs. The image of the point is in a line perpendicular to the mirror passing through the point of the pencil, and as far behind the mirror as the point is in front of it.

IMAGE OF AN OBJECT BY A PLANE MIRROR.

EXPERIMENT 160.

Obs. The image of each point of the object is located just as the point in the preceding experiment was.

The image of the right eye forms the left eye of the image of the face.

IMAGE BY TWO PLANE PARALLEL MIRRORS.

EXPERIMENT 161.

Obs. Several images can be seen arranged in a row at regular intervals.

IMAGE BY TWO PLANE MIRRORS AT AN ANGLE.

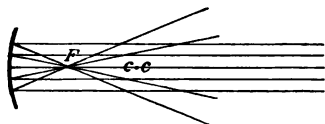
EXPERIMENT 162.

Obs. Three images can be seen with the mirrors at 90 degrees, five with them at 60 degrees, and eleven with them at 30 degrees.

CONCAVE MIRROR.

EXPERIMENT 163.

Obs. The reflected rays converge, and pass through a point in front of the mirror.



Focus is Latin, meaning hearth, fireplace.

Inf. The centre of curvature is so called because it is the centre of a sphere of whose surface the surface of the mirror forms a part.

IMAGE BY A CONCAVE MIRROR.

EXPERIMENT 164.

Obs. An inverted image smaller than the candle is formed near the principal focus, between it and the centre of curvature.

EXPERIMENT 165.

Obs. As the candle comes nearer to the centre of curvature, the image also approaches that point and becomes larger.

EXPERIMENT 166.

Obs. When the candle is placed within the centre of curvature, the image is formed beyond the centre of curvature, and is larger than the object.

EXPERIMENT 167.

Obs. No image is formed when the object is at the principal focus or within the principal focus, and when the object is at the centre of curvature the image is confused with the object; but if the object is placed just at the right of the centre of curvature, the image is formed at the left.

Inf. Light starting from the principal focus is reflected as parallel rays, and does not come to a focus. Light starting within the principal focus is reflected as diverging rays, and does not come to a focus. Light starting from the centre of curvature strikes the mirror perpendicularly, and is reflected directly back to the object, forming no separate image.

L. REFRACTION.

EXPERIMENT 168.

Obs. The rays are bent downward from the pencil on entering the water.

EXPERIMENT 169.

Obs. These rays are not refracted.

DIRECTION OF THE CHANGE.

1. Water is denser than air.
2. The light is bent toward the perpendicular as it enters the water.
3. On passing from air (a rarer) into water (a denser medium), light is bent toward a perpendicular to the surface separating the two media.

EXPERIMENT 170.

Obs. The cent is now visible.

Inf. The light must have passed in a broken line from the cent to the eye. On passing from the water into the air the light was bent from the perpendicular to the surface of the water.

BY A DOUBLE-CONVEX LENS.

OF PARALLEL RAYS, PRINCIPAL FOCUS, FOCAL DISTANCE.

EXPERIMENT 171.

Obs. On leaving the lens the light converges to a certain point, and, passing through it, continues as a diverging pencil.

Inf. The distance of the principal focus from the lens is called the focal distance.

IMAGE OF AN OBJECT.

EXPERIMENT 172.

Obs. An inverted image larger than the object is formed at considerable distance from the lens.

EXPERIMENT 173.

Obs. As the candle is moved away from the lens, the image becomes smaller, and is formed nearer the lens.

When the image is of the same size as the object, the flame is twice the focal distance from the lens.

HUMAN EYE.

(See Physiologies.)

SIMPLE MICROSCOPE.

The image appears erect, and considerably larger than the object.

COMPOUND MICROSCOPE.

EXPERIMENT 174.

An inverted image much larger than the object is seen.

EXPERIMENT 175.

Description same as in Experiment 174.

REFRACTING TELESCOPE.

EXPERIMENT 176.

A small inverted image is seen.

EXPERIMENT 177.

A small inverted image is seen.

The refracting telescope differs from the compound microscope in having the object at considerable distance, the object glass larger than the eye glass, and the image much smaller than the object, but near the eye glass. The large object glass takes in much more light from the object than the eye could, and enables us to see distant objects distinctly.

REFRACTION BY A PRISM. SOLAR SPECTRUM.

EXPERIMENT 178.

A small image of the sun is formed on the screen.

EXPERIMENT 179.

The image is formed higher up, is lengthened out, and has the colors of the rainbow.

The light is bent upward on passing through the prism, thus throwing the image higher. It must be refracted unequally, in order to lengthen the image; and the unequally refracted rays are of different colors.

The colors of the spectrum are violet, blue, green, yellow, orange, and red.

Inf. 1. The violet rays are refracted most.

Inf. 2. The red rays are refracted least.

PRACTICAL QUESTIONS.

1. Objects cast their longest shadows in the morning and at night, because the sun is lower at those times.
2. They cast their shortest shadows at noon.
3. In the polar regions the shadows are always long.
4. Within the tropics upright objects cast no shadows at noon when the sun is directly overhead.
5. The half of the moon which the sunlight falls on shines.
6. It does not shine upon the earth when it is directly between the sun and the earth.
7. That portion of the lighted half of the moon which is turned toward the earth at any time shines upon the earth.
8. The stars shine by their own light.
9. Planets are heavenly bodies which revolve about the sun in nearly circular orbits, and shine by the sun's light, while the fixed stars are outside of the solar system, and shine by their own light.
10. (Answers will vary.)
11. The earth shines with the sun's light.
12. Light from heavenly bodies in entering and passing obliquely through the earth's atmosphere is continually coming into denser media, and is being refracted downward. Thus light starting from a

heavenly body below the horizon may reach the observer, and the body be seen.

13. Light from objects under the water is bent downward on leaving the water obliquely, and seems to come from points higher than it did come from.
14. In Experiments 154, 164-6, 172-3, and 178-9.
15. In Experiments 159-162, 170, and 174-7.

XIV. CHEMISTRY OF AIR AND WATER.

THE COMPOSITION OF THE AIR.

EXPERIMENT 180.

Obs. A light, smoky, or cloudy gas is formed, and fills the jar. The phosphorus stops burning after a short time. The cloudy gas gradually disappears, and the water rises and fills about $\frac{1}{5}$ of the jar.

Inf. 1. The cloudy gas must have gone into the water.

Inf. 2. It could not have been P alone.

Inf. 3. A portion of the air may have combined with the P.

Inf. 4. The cloudy gas was absorbed by the water, and left some room for water.

Obs. 2. The P was not all consumed. (It may be if the jar is not placed *promptly* over the lighted P.)

Inf. 5. The part of the air which united with the P must have been all consumed.

Obs. 3. The volume of the part of the air left in the jar is about 4 times as great as that of the part which united with the P.

Inf. 6. Phosphorus pentoxide is a compound.

Inf. 7. About $\frac{1}{5}$ of the air is O.

Inf. 8. About $\frac{4}{5}$ of the air is N.

PREPARATION OF OXYGEN.

EXPERIMENT 181.

If the delivery tube were not removed from the water before the flame was taken from the test tube, the gas in the tubes would cool and contract, and the water rush in and break the tubes by suddenly cooling them.

PROPERTIES OF OXYGEN.

EXPERIMENT 182.

The glowing coal bursts into flame, and burns brilliantly.

EXPERIMENT 183.

The charcoal burns brightly, sending out sparks.

EXPERIMENT 184.

The sulphur burns faster than in the air, with a bluish flame.

EXPERIMENT 185.

Obs. The sulphur burns, and the iron takes fire and burns with bright scintillations.

Inf. 1. Oxygen has a strong affinity for some other elements.

Inf. 2. Oxides of carbon, sulphur, and iron have been formed in these experiments.

COMBUSTION.

EXPERIMENT 186.

Obs. Moisture (water) collects on the inside of the chimney.

Inf. 1. Water is produced in the burning of the candle.

Inf. 2. As it is formed by combustion, one element is probably O.

EXPERIMENT 187.

Obs. 1. Bubbles of colorless gas rise from the paper, and fill the bottle.

Obs. 2. The splinter ceases to burn, and the gas takes fire (with a slight explosion at the mouth of the bottle) and burns with a yellowish flame.

Obs. 3. Moisture (water) forms on the inside of the bottle.

Inf. 1. This water was formed in the process of combustion.

Inf. 2. It must have been formed from oxygen and the gas which was in the bottle.

Inf. 3. The gas came from the water which was in the bottle, as it united with O to form water.

1. This gas is colorless, burns with a pale yellow flame (and explodes when mixed with air), but wood will not burn in it.

Inf. 4. Water is composed of oxygen and hydrogen.

Obs. 4. Moisture (water) gathers on the chimney.

Inf. 5. The oxygen comes from the air, and the hydrogen must come from the oil or gas.

EXPERIMENT 188.

Obs. 1. Bubbles come from the end of the lower tube up through the water.

Inf. These bubbles consist of air.

Obs. 2. The water does n't seem to be affected.

EXPERIMENT 189.

Obs. 1. The lime-water is not affected in the first part of the experiment, but turns milky in the last part.

Obs. 2. The lime-water becomes clear, and a fine white solid collects on the bottom of the bottle.

Inf. 1. The coloring of the liquid was due to the small particles of the white substance floating in it.

Inf. 2. Two or more substances must have combined to form this new one.

Inf. 3. One of these substances must have come from the burning candle, and one must have been in the lime-water.

Inf. 4. That which came from the candle could not have been water, as there was water in the lime-water before, and the white substance was not formed.

Inf. 5. The substance which came from the candle was a gas.

EXPERIMENT 190.

Inf. 1. The substance left in the jar cannot be oxygen. If it were, the charcoal would continue to burn in it.

Inf. 2. It was formed from the charcoal and oxygen.

Inf. 3. *Carbon* combined with the oxygen.

EXPERIMENT 191.

The flame is extinguished.

EXPERIMENT 192.

The flame is extinguished.

EXPERIMENT 193.

Obs. The lime-water turns milky.

Inf. 1. It was *carbon dioxide*.

Inf. 2. Water and carbon dioxide are formed in the burning of a candle.

CHANGES IN AIR IN THE HUMAN BODY.

EXPERIMENT 194.

Obs. Moisture is condensed upon the glass.

Inf. Water is given out in breathing.

EXPERIMENT 195.

Obs. The lime-water becomes milky.

Inf. 1. Carbon dioxide is given out in breathing.

1. These substances given out in breathing are the same as those formed in the burning of the candle.

2. Oxygen is taken out of the air in combustion.

Inf. 2. Oxygen is taken from the air in breathing.

Inf. 3. In breathing the same air over and over, its supply of oxygen becomes insufficient, and it receives impurities, consisting of animal matter, which are injurious.

Inf. 4. A lighted lamp or a gas jet injures the air of a room for breathing.

Inf. 5. There was not sufficient oxygen left in the air to combine with the materials of the match.

Inf. 6. Such air was unfit to breathe.

Inf. 7. The air of an occupied room must be constantly changed to keep it fit for breathing.



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